

SHIP SHAPE

THE BIGGEST OIL TANKERS are as high as a 20-storey building and can hold over half a million tonnes of crude – enough to run 14 million cars. They are so long that crew members ride bicycles to travel from bow to stern. Building such monsters requires special methods and super-scale facilities.

As with all ships, a supertanker begins life as a specification and a design. The specification, supplied by the shipowner, includes details of the cargo to be carried, together with the vessel's proposed speed and operat-

ing range. It is then the task of a naval architect to come up with a design to match these requirements. For instance, the amount of cargo that the owner wants carried determines the size of the cargo holds. The weight of cargo and the specified speed decide what the engine power should be.

Hydrodynamic tests

The naval architect builds up a complete 3-D picture of a proposed new ship in a computer's memory, then subjects it to a battery of simulated structural and hydrodynamic tests. When the design is complete, it is presented in a report to the shipowner.

Metal-hulled ships

are made by cutting sheets of metal, bending them in a huge press and riveting or welding them together to make a joint that is watertight.

Huge cranes are used to move parts of the ship into place. The bridge, the engine and sometimes whole sections of the ship are made separately and swung into position.



Berenguer/Jerrican

Robert Harding Picture Library





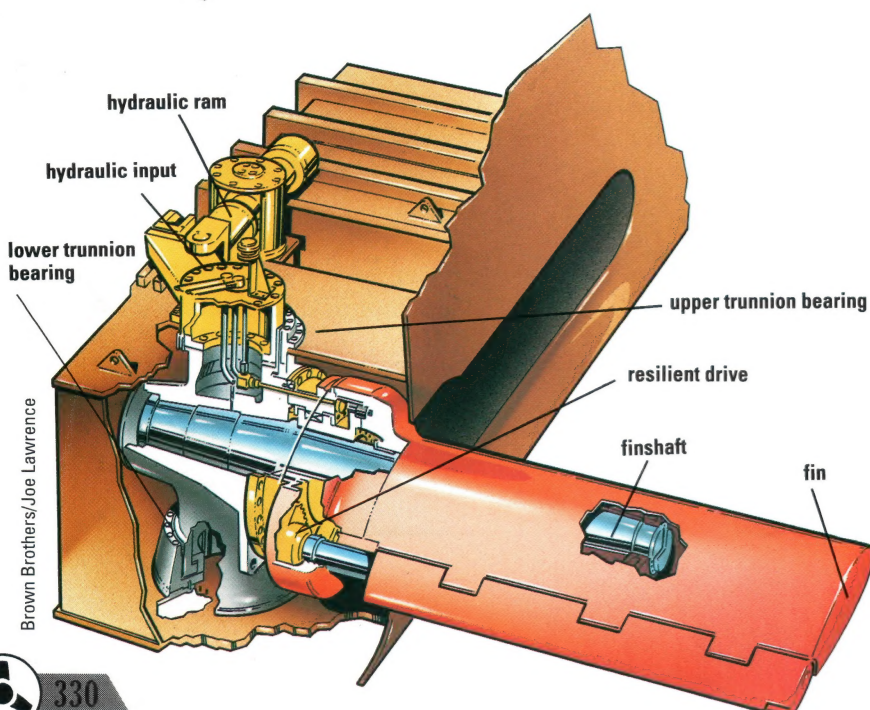
If the owner agrees with the plans, the next stage is to build a scale model, usually from wax, for testing in a large water tank. The testing-tank has a travelling arm above it that can be moved at various speeds while

Painting the hull is done with a remote painting arm at the Yokohama Works in Japan. The inside of a ship is decorated, or renovated (above) when the ship is in the water, leaving the slipway or dry dock free for building or repairing hulls.

SUPERTANKERS

The largest supertanker afloat is the *Jahre Viking* with a deadweight of 564,650 tonnes, 459 metres long and 69 metres across. A ship of this size is extremely difficult to manoeuvre. When travelling at speed, for instance, a supertanker needs several kilometres of searoom in which to stop and typically has a one km turning circle. For this reason, onboard computers are used to maintain the ship's course and control most of its movements.

A stabilizer fin counteracts the roll of a ship. It is tilted about the finshaft by a resilient drive. This unit is mounted on trunnions and retracted by a hydraulic ram.



bottom. Next, the main watertight bulkheads, cut by computer-controlled machinery to high accuracy, are fitted in place. These form the framework on which the side plates and decks are attached.

Launching

Finally, the curved stern plates are added and bent to shape by computer-guided hydraulic presses. The hull is then launched into deep water down the slipway.

Building and launching a vessel as big as a supertanker from a slipway



holding the model. This allows the naval architect to measure its resistance to the flow of water and determine the size of engine needed. Detailed building plans are then drawn up and sent to the shipyard.

Slipways

The traditional way of constructing ships, and the one still often used for smaller vessels, is on a sloping slipway. First, the keel is laid down and plates welded to it to form the ship's



Mitsubishi Heavy Industries Ltd

Tony Stone Photo Library, London

A dry dock is used when a ship needs repair. The ship is sailed in, the gates are closed and the water is pumped out until the ship rests on huge bilge blocks.

would be impossible, however. As the ship went down the slipway, the bow would still remain on land while the stern would be in the water. The central section would be hanging in mid-air with nothing to support it, and

so the ship would break its back.

To prevent this happening, supertankers are assembled, like offshore oil platforms, in specially built dry docks. These are giant concrete basins at the water's edge, sealed off from the sea by massive watertight gates. Some of the largest such docks are to be found in the shipyards of

REPAIRS AND REFITS

Each country that registers ships has strict rules about safety. These specify, among other things, when a ship must go into dry dock for inspection and repairs. With the ship's hull exposed, engineers check over the steel plating looking for cracks or signs of corrosion. The hull is thoroughly cleaned, repainted, and repaired by welding on new steel plates. Mud and other debris is cleared away from the propeller. During a complete refit, major items of equipment, including the engines, may be taken out and replaced.

Japan and South Korea.

One at Koyagi, Nagasaki, Japan, completed in 1972, can accommodate vessels up to a million tonnes deadweight. It measures 990 metres long by 100 metres wide. It is surpassed, however, by the 131-metre

Mitsubishi Heavy Industries Ltd

The Goliath crane at Mitsubishi's Koyagi shipyard can lift up to 600 tonnes and moves up and down the kilometre-long dry dock on rails. This one is moving the entire superstructure of a ship into place in one piece. The steel plates used to make the ship's hull are shaped in a hydraulic press (above) which can exert a force of 8,000 tonnes.



Limier/Jerrican

Huge tanks in the walls of a floating dock are filled with water, sinking it so the ship can sail in. Then they are emptied, lifting the ship out of the water.

wide Daewoo Okpo Number One dry dock on Choje Island, South Korea, which can house tankers of up to 1.2 million tonnes deadweight.

Today, the trend is towards making large, prefabricated sections of hull under cover in an assembly shop alongside. Various parts of the ship can be worked on at once and jobs such as painting are not held up by bad weather. As each section is completed, cranes lift it into position while

welders fix it to the rest of the hull.

In some shipyards, the process of building section by section has been taken a stage further. Tracks link the assembly shop with the dock. The stern section is put together first, on the track inside the workshop. Then it is pushed along the track until only the edge to be joined to the next section is left inside. When the next section is ready, it is welded to the stern unit, and so on, until the ship is complete.



Modular construction

In some ways, building a supertanker is quite straightforward, despite the vessel's great size. The tanker is constructed from modular sections, each of which is fitted out with all the nec-

essary pipes, heating elements, and other equipment for handling the oil cargo, before being lifted and welded into position in the dry dock.

When the hull of the supertanker is complete, the ship is ready for fitting out. Engine, propeller and shaft, rudder, and countless other items of machinery are lowered into position. With the main deck in place, the superstructure is added, including the crew's quarters and bridge. Finally, the cranes and mass of scaffolding surrounding the ship are removed.

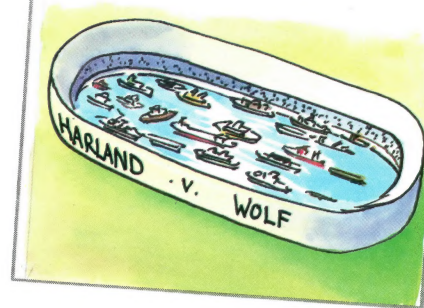
If the dry dock is large enough, the tanker will have been built in one piece. The dry dock is then flooded so

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Just amazing!

SHIP AHoy!

THE WORLD'S LARGEST SHIPYARD, HARLAND AND WOLFF, QUEEN'S ISLAND, IN NORTHERN IRELAND, COVERS AN AREA OF 120 HECTARES – EQUIVALENT TO 176 FOOTBALL PITCHES.



Paul Raymond





The Norwegian ore carrier Berge Stahl is the biggest dry cargo ship in the world with a deadweight of 364,767 tonnes. Some oil tankers are bigger.

that watertight gates can be opened, allowing the sea to enter and float the ship. In other cases, a tanker may have been constructed in two separate sections, which are floated and welded together in the water.

After launch, the ship is berthed at a pier for final outfitting. In the case of, say, an ocean-going liner this would involve extensive work on passenger accommodation and facilities. But for a tanker it is a fairly minor undertaking, limited to such details as deck gear, lifeboats, and crew quarters.

The next stage is to run various tests on the supertanker while it is moored to the dockside. Checks are carried out to see that all electrical and

hydraulic systems, pumps, radar, computers, steering gear, and so on, are functioning properly. The engines are started and the propeller turned over at low speed while engineers monitor the performance.

Finally, the vessel is cast off and taken out for sea trials. In a series of tests, the tanker's speed is progressively increased until it reaches the maximum speed specified in the contract between the builder and the shipowner. Sea trials are conducted over a measured course of sheltered water, away from other sea traffic.

First cargo

To simulate carrying a full cargo can be difficult for certain types of ship, but for supertankers it is easy: the tanks are simply filled with seawater. Finally, when the owner is satisfied, the supertanker, with its crew on board, sails away to load up its first real cargo of crude oil.



The Mitsui Rotas system rotates huge sections of an oil tanker while they are being welded. Then it slides them into their final position in the ship.

INTO THE FUTURE

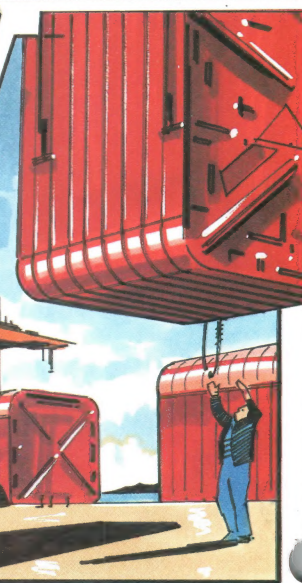
SEA TRAIN



▲ Ships could soon be replaced by 'sea trains'. These would have a conventional bow and stern section, containing the engine and crew quarters.



▲ The mid sections, though, would be sealed cargo containers that would be marshalled like a train in a port. The bow and stern sections would then be added.



▲ When the sea train stopped off at port, new sections could be added and others removed – either to be joined to another sea train or opened if at their destination.

TRUE

OR FALSE

FAKE OR REAL: WITH FAMOUS paintings and other works of art fetching millions on the international market, forgery is a big problem. To avoid embarrassment and loss of money, museums and art galleries are turning to an increasingly powerful array of scientific instruments to establish authenticity.

Forgery is not new – Roman sculptors copied classical Greek statues and sold them as originals, 2,000 years ago. Nor is the use of technology to analyse art all that recent – one of the first objects William Roentgen examined with the X-ray machine he invented in 1895 was a painting.



Probing instruments

But in the past few years, techniques that can probe an art object at levels invisible to the human eye have become far more sensitive. At the same time, the high demand for art has led to a rise in the number and sophistication of forgeries.

Most methods used to detect forgeries have not been developed specifically for that purpose. Instruments that can probe, non-invasively beneath the surface of a painting, for example, are used mainly by art experts for finding out more about the

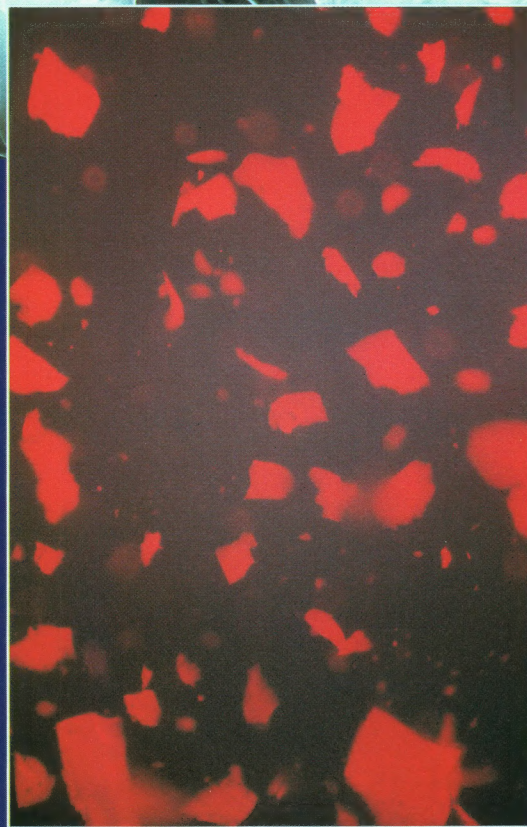
history, techniques and materials of genuine masterpieces.

In a technique called infrared reflectography, the painting is bombarded with infrared rays from lamps, and then viewed through a camera equipped with an infrared filter. The infrared light waves penetrate the various layers of pigment but are reflected by any charcoal or metal point underdrawing that lies beneath the surface of the paint.

Photographing a painting with

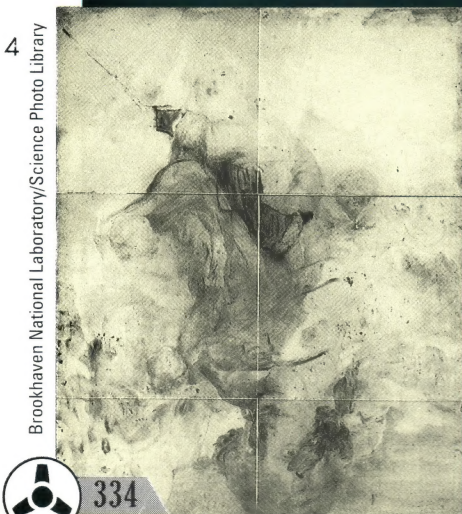
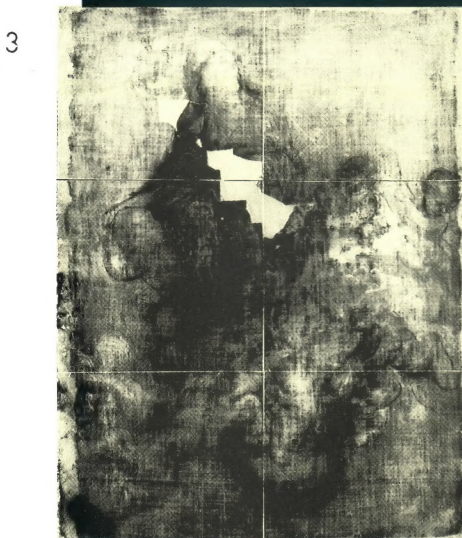
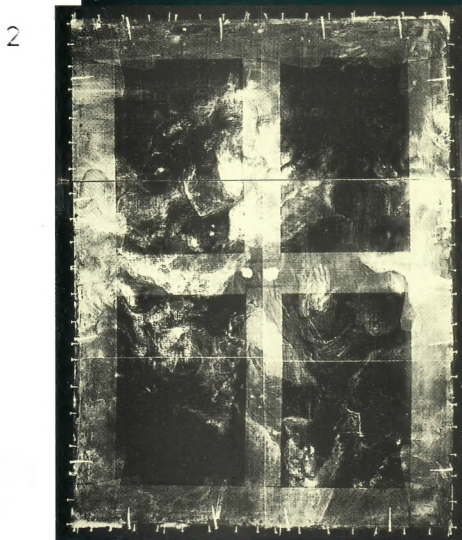
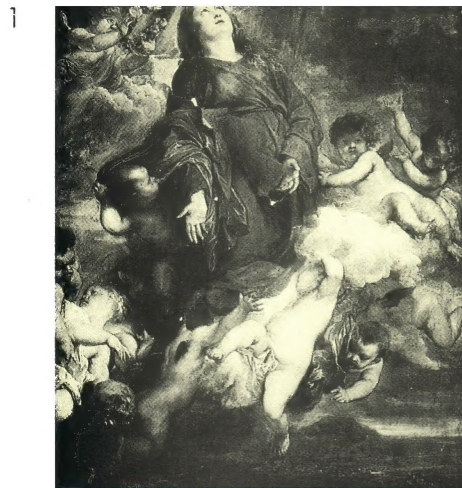
An expert at the Louvre in Paris examines the X-ray of a painting for details of draft sketches and overpainting that might reveal the masterpiece as a fake. Ultraviolet light is also used to study varnish and pigments (inset).

Labat/Miard/Jerrican



Conservation Dept, Tate Gallery London





Hidden self-portrait of Van Dyck. The original (1) reveals hints of a face under X-ray (2). A few hours after irradiation with neutrons, manganese in the base appears (3). Four days later, phosphorus in the charcoal sketch shows up (4), best viewed upside down.

The results of such infrared and X-ray studies often prove surprising. X-ray photographs taken at the Los Angeles County Museum of Art of a 17th century Flemish masterpiece, for example, called *The Crucifixion*, showed that beneath the surface lay an entirely different painting.

Trustees of the British Museum



This Chinese bronze vessel appears totally genuine under ordinary light. But X-rays revealed a crack, clumsily repaired with solder. Ultraviolet light shows that the repairers have faked part of the decoration with a new and different patina (below).



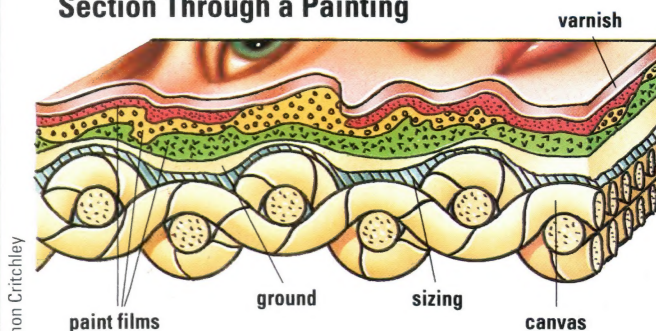
Trustees of the British Museum

X-rays, though, can reveal intermediate layers of paint between the first sketch and the top layer of varnish. Low-energy X-rays are reflected by the top coat of paint, while high-energy X-rays penetrate to deeper layers.

Recently, the use of digital video cameras has made these methods still more powerful. A digital video camera assigns a number value to the brightness at each point in a picture. This data can then be fed directly into a computer so that the image can be processed in various ways.

For instance, the information in a low energy X-ray photograph of the top layer of paint can be subtracted

Section Through a Painting



Simon Critchley

Different layers of a painting yield clues to the forgery detective. Over the years different types of top surface varnish, paint, canvas and size have been used. They all degrade differently over time.

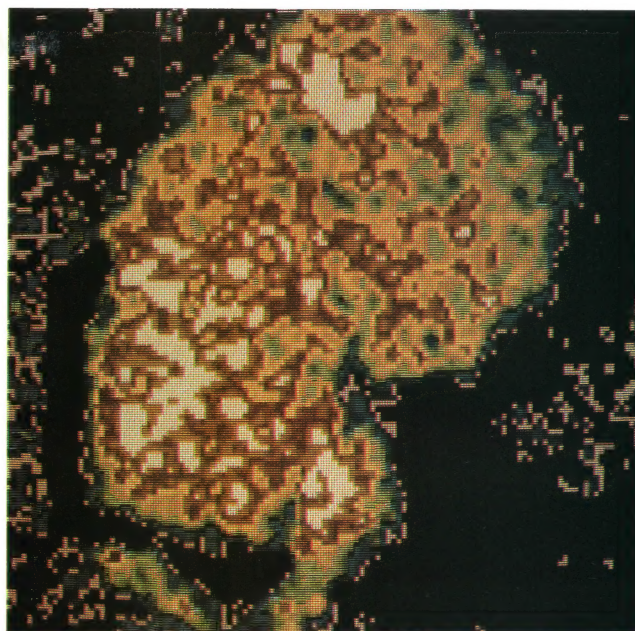
from a high-energy X-ray image of a lower layer. The result is a much clearer view of what lies below the surface. The computer can even subtract the effects of the cracking of glazes or the grain of wood.

Even the greatest artists changed their minds during the course of a particular work. Detail that may appear in the original sketch, as shown by infrared photographs, is often missing or greatly altered in the final painting.

Sometimes these analysis techniques prove that a lesser artist painted what previously had been credited to a great master. Using an infrared camera at the Isabella Stewart Gardner Museum in Boston, an expert spotted a signature on a work thought to have been by Rembrandt. The signature, in fact, belonged to one of Rembrandt's students.

Analysis by infrared and X-ray has shown that many paintings supposedly by Rubens were only started by him, then given to his students to

A digital false colour X-ray image of a gold brooch from Lombardy reveals the presence of cadmium, a constituent of modern gold solders. This shows that it could not have been made in the 17th century as claimed.

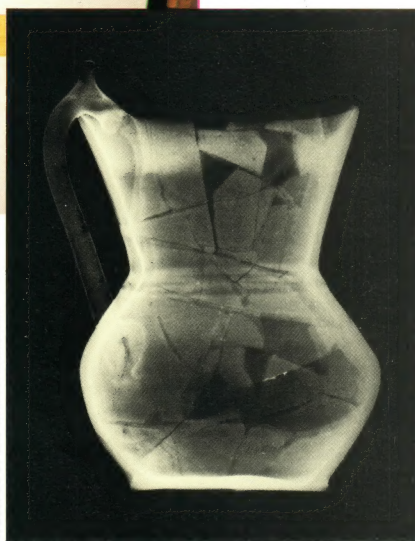


Trustees of the British Museum

The British Museum's X-ray machine showed that a jug previously thought to be genuine was a collection of pieces stuck together and repainted (right).

complete. Far more damaging to the international art market, however, are the hundreds of paintings once thought to be valuable masterpieces that, when examined rigorously with modern technology, have proved to be recent fakes.

Although a painting may convince the art experts that it is a genuine masterpiece, photographic analysis may show that the sketch underneath is



Trustees of the British Museum

completely different in style and done by a forger. But the skill of many forgers means that more powerful methods are often needed to decide what is genuine and what is fake.



Radiography

Providing information about the distribution of different elements and the pigments they make up, neutron-activation radiography involves placing the painting in a beam of neutrons coming from a nuclear reactor. Neutrons – tiny, uncharged particles produced in huge numbers during the break-up of radioactive substances – are absorbed by the paint; and each element in the painting re-emits gamma rays – high-energy rays – at a unique and recognizable wavelength. Captured on photographic plates, these gamma rays reveal the type and amount of each element present.

Since the use of specific pigments

Complex computer-designed laser-generated patterns are added to the background of banknotes to make them more difficult to forge.

is often characteristic of specific periods or specific artists' work, this method can be used to spot extremely sophisticated forgeries. Among other things, it can determine whether a painting thought to be of 19th century origin contains, say, titanium white, a pigment which was first manufactured in the 20th century.

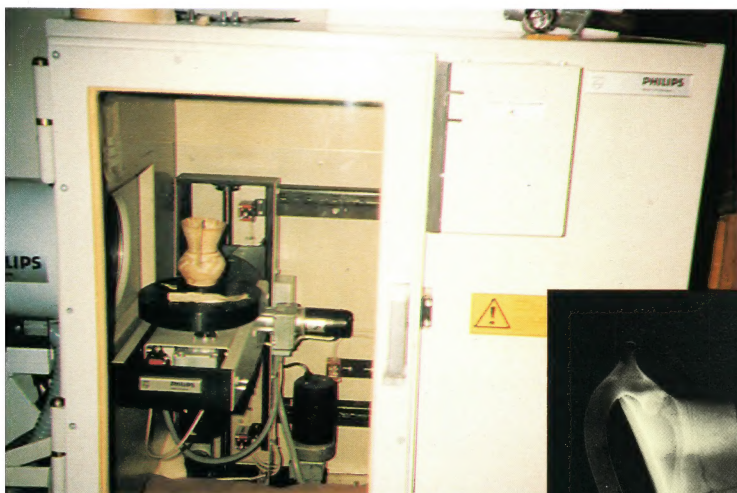
Another method of examining the make-up of oils and resins in paint, which helps establish the period from which a work of art dates, is laser fluorescence spectroscopy. When a laser is directed on to a painting the oil and

CASHING IN ON FAKES

Recently, in Canada, a man was caught making counterfeit money with the help of a full-colour laser copier that he bought for US\$47,000. The fake Canadian and American banknotes that he produced on the machine were virtually indistinguishable from the real thing. But in the future passing off forged money is likely to be much harder. A Canadian researcher, for example, has perfected a method for coating banknotes with a thin, flexible film of coloured metal. These iridescent films, only a tenth of a micrometre thick, produce patterns that vary according to the angle from which they are viewed. By tilting such a banknote it would be easy to see whether or not it was a fake.

resin molecules fluoresce, or give off light at special wavelengths that reveal their composition.

Sculptures are notoriously difficult to authenticate. Sometimes a forgery may give itself away by slight discrepancies in style or condition for its supposed age. But usually the expert has to turn to highly specialized methods of analysis. One of these involves taking photographs through a microscope, digitizing the images, then examining the results with a computer. Tiny irregularities in the surface of



De La Rue Co plc



the material can help to distinguish a good copy from the real thing.

In 1984, the Getty Museum in California had to decide whether or not to buy a Greek marble figure of a youth, said to date from about 530 BC.

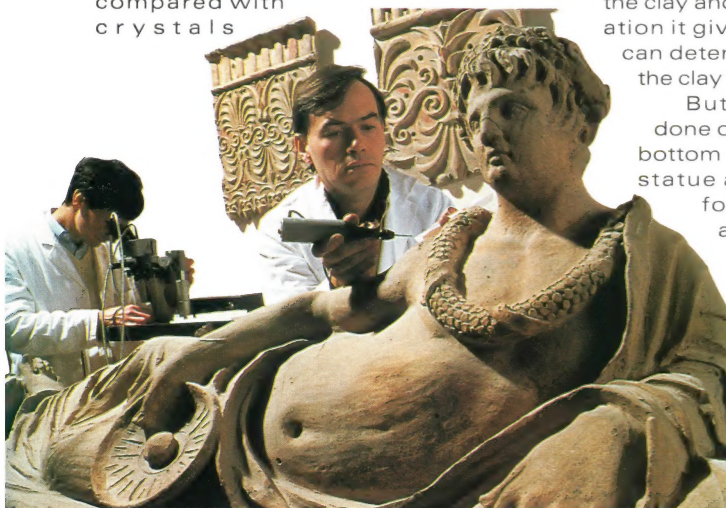
Customs officials in Los Angeles use a steamroller to crush a batch of fake Cartier watches. Many imitations of famous brands are made in the Far East.



Gamma/Frank Spooner Pictures

Some experts had suggested that it might be a fake, partly because it was in such good condition.

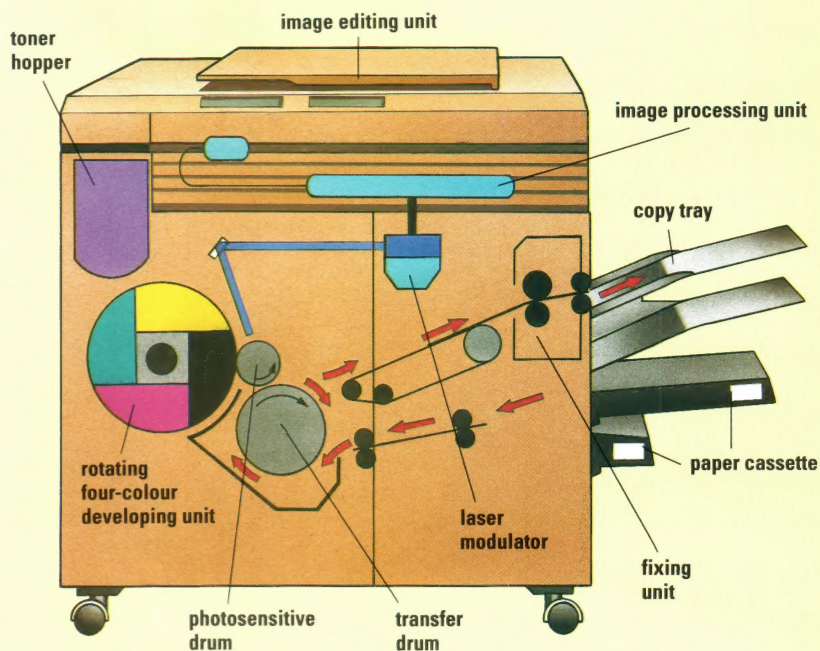
During a thorough study of the piece by the museum, a tiny core sample, 1 centimetre across and 2 centimetres long, was taken from a crack in the figure's right knee. The marble crystals in this were then compared with crystals



taken from the surface of a statue of an authenticated date that had been subjected to aging and weathering. From this and other tests it was decided that the statue was genuine and that the museum should buy it.

As the experts use more and more sophisticated methods of detecting forgeries, so the forgers themselves

COUNTERFEITING MADE EASY



A semiconductor laser is used to reproduce images in a laser copier. To prepare for copying, the photosensitive drum is exposed to electricity to build up a uniform charge on its surface. Signals sent from the reading unit, which scans the original image, activate the laser, turning it off and on. When the

laser is on it strikes the drum, partially neutralizing the charge. Areas not struck keep their charge. The partially neutralized areas attract toner, which is then transferred to paper to make the copy. The drum is recharged four times, once for each toner colour – yellow, red, blue and black.

Steve Latibeaudiere

make progress. A technique known as thermoluminescence dating provides a good example. This method exploits the fact that clay absorbs radiation with time. It releases this radiation when heated so, by heating the clay and measuring the radiation it gives off, art scholars can determine roughly when the clay was last heated.

But the test is usually done on a sample from the bottom of the leg of a pot or statue and, knowing this, forgers often glue an ancient leg on to a modern piece. Another, equally

dip sculptures in acid or bury them in dung heaps to produce an ancient-looking coating or patina. He may employ lasers to map the surface of an old coin and then micromachine the same surface on to a fake coin. Or the forger may use the latest photocopying or high-quality printing technology to make bogus prints. As the stakes rise, the battle between expert and forger looks set to intensify.

Engineers at the Louvre take a tiny sample of the marble from an Etruscan sarcophagus to check it was made in the 11th century.

Just amazing!

FORGING A HEAD

PARISIAN ARTIST ANTONIO BIN HAS PAINTED THE WORLD'S MOST FAMOUS PORTRAIT, THE MONA LISA, AT LEAST 300 TIMES. HIS HONEST FAKES SELL FOR UP TO \$1,000 EACH.



Paul Raymond

Q HUMIDITY DAMAGE

Q POLYMERS

Q ACID PAPER

WELL PRESERVED

The Sphinx, Egypt, under an imaginary protective cover. Computer-generated imagery shows a movable canopy for shelter from the elements.

PRICELESS WORKS OF ART all over the world are under constant threat from the environment, malicious vandals, and professional art thieves. The challenge to art conservators is to find better methods of preserving items of historical value.

Very old paintings are especially vulnerable to large changes in hu-

midity, or the concentration of water vapour in the atmosphere.

Before about 1450, most European paintings were done on wooden panels, which swell and shrink across the grain as the humidity varies. In Britain, for example, the humidity in a museum or gallery can vary from 25 per cent in midwinter to 90 per cent in summer. As the wooden support bows and shrinks, the

paint on the surface cracks in a fine network called craquelure.

The problem can be made worse if a wood-panel is moved to a location with very different atmospheric conditions. In certain parts of the United States, for instance, the average humidity is low all year round, so that a European painting used to a higher humidity may be badly affected. The best solution is to air-condition

Gamma/Frank Spooner Pictures

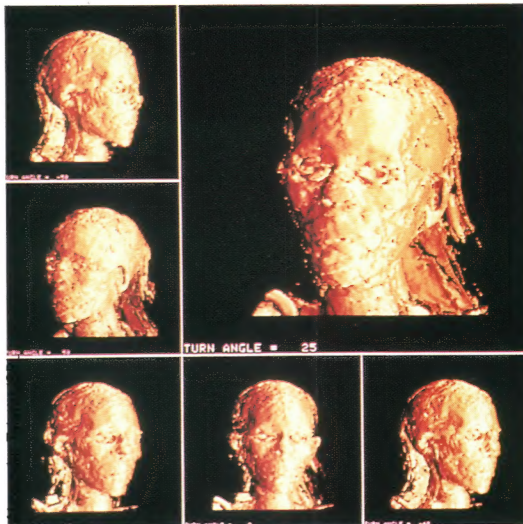


the area in which the painting is to be stored or displayed. The air-conditioning keeps the humidity more or less constant at the least-damaging level, usually around 55 per cent. For the same reason, furniture and canvas paintings are best kept in an air-conditioned environment.

Human damage

Occasionally, a vandal will launch a mindless attack on a piece of art, throwing acid over a painting or striking a sculpture with a hammer. But visitors to museums, art galleries, and historical sites can also cause serious damage without realizing it.

Simply by breathing in an enclosed space, people cause the humidity to rise. Many of the wall paintings in Egyptian tombs have begun to flake



A computer-generated image of a female Egyptian mummy. Compiled from computer tomography X-ray data, it was obtained without having to open the precious coffin.

as weak acids. Sulphur dioxide is especially damaging to stone. It reacts with the mineral calcite, contained in marble and limestone, to produce a surface layer of gypsum. Unlike calcite, gypsum will dissolve in water. So, when it rains hard, the gypsum surface layer is washed away, leaving the fresh stone underneath bare to renewed attack.

By this process, decoration on the Acropolis in Athens is

being eroded faster now than at any other time in the building's 2,300-year history. Similarly, frieze panels on the Parthenon have lost much of their detail because of sulphur dioxide in the smog over the Greek capital. A panel taken from the Parthenon and stored in the British Museum since the early 19th century, by comparison, shows relatively little sign of weathering.

As well as damaging stonework, chemicals in the atmosphere can cause discoloration. This happens when soot and ash become trapped in the surface layer of stone as it is chemically transformed. The first task

off because of the hundreds of visitors that have crowded daily into the enclosed spaces, moistening the air with their breath. In cases like this, there are two possible courses of action: to install air-conditioning or limit the number of tourists allowed.

An unblemished angel, as it appeared when first created in 1880 for Cologne Cathedral. Now, sulphur acid rain has dissolved the stone, and dirt on the surface contains a lot of calcium sulphate, which cannot be removed without damaging the stone. Algae live on organic dust and nitrogen given off by traffic. Their metabolic products also help to dissolve the stone.

Cologne Cathedral



A ravaged angel in need of restoration. The effects of industrial pollution on the soft limestone are intensified because of its exposed position.



RIDDLE OF THE SPHINX



A 90-kilogram, 2-metre-tall instrument on the back of the Great Sphinx in Egypt may help to solve a modern riddle about the half-human, half-lion structure: why is it crumbling? Between 10 and 30 centimetres of the surface of the Sphinx are wearing away every century. The instrument contains sensors that collect information every 10 to 15 seconds on wind speed and direction, rainfall, humidity, condensation, air temperature, solar radiation, and the surface temperature of the Sphinx. By examining this data, scientists hope to decide which of several possible processes may be causing the deterioration. These processes include rising ground water, erosion by wind and sand, and wide fluctuations in temperature.

Gamma/Frank Spooner Pictures

Just amazing!

BRITTLE BOOKS

90 PER CENT OF BOOKS PUBLISHED IN AMERICA BETWEEN 1900 AND 1949 WILL BE TOO WEAK FOR GENERAL CIRCULATION BY THE YEAR 2000.



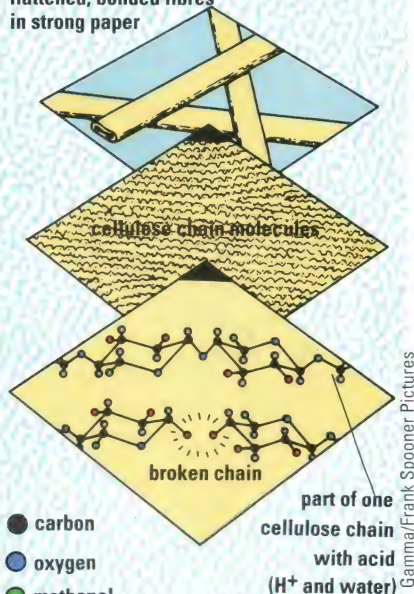
Paul Raymond

Sulphur dioxide

From the cathedrals of France to the ancient temples of Greece, some of the world's most prized stonework is suffering severe damage from airborne pollution. Oxides of sulphur and nitrogen are produced when oil, coal, or natural gas are burned, such as in car engines and power stations. These oxides then mix with water vapour in the air and fall to the ground

Acidic Weakening of Paper

flattened, bonded fibres
in strong paper



Gamma/Frank Spooner Pictures

The slight acidity of wood pulp used to make paper eventually attacks the molecule chains of the cellulose backbone that gives paper its strength and results, over time, in brittle paper.

in protecting a sculpture or building from further decay, then, is to clean it and remove unwanted substances from the surface. This can be done by brushing the stone or blasting it with air, water, steam, or grit.

Next, the cleaned, exposed masonry is treated. One of the most effective

means of a curing agent. Some of the polymers used today not only bind the particles of stone together, they provide additional protection by repelling water from the surface.

Stained glass

Mediaeval stained-glass windows are particularly fragile and prone to damage. The usual method of protecting artwork inside a building, by air-conditioning and other environmental controls, is impractical inside a cathedral or church. Instead, the best solution is to use double-glazing.

A protective pane of glass, not attached to the stained-glass panel, is installed on the outside. Then, the temperature and humidity of the air gap between the panes is carefully controlled. The result is that the new, protective window absorbs changes in the outside temperature while at the same time collecting moisture. Meanwhile, the stained glass stays uniformly warm and dry.

In great libraries and archives millions of books are literally falling apart because of a new way of making

Sipa Press/Rex Features Ltd



or linen rags that were used before.

Unfortunately, book publishers did not know that the wood pulp's slight acidity would eventually prove disastrous. The acid attacks the long chains of cellulose molecules in the paper, making them shorter and shorter until the paper decomposes.

Book preservation

The necessity of book preservation, therefore, needs to be applied on three fronts. The first is to see that the printing industry adopts acid-free paper for books. The second is the conservation of books that are already too brittle for use. Methods employed in this category include microfilming used for long runs of brittle books and newspapers and digital optical discs used by the Library of Congress, US, for recent, short, high-use articles and reports. Traditional methods of hand conservation are used for artefacts of special importance. This process is expensive and time-consuming as it involves washing out the acid in water and then providing an alkaline buffer to a text block which has been pulled from its

WELL PRESERVED

'Nefos' – the Greek for cloud – is the name given to the smog that hovers over Athens, one of the world's most polluted cities. When the pollution is severe, hospital admissions rise.

A Caryatid – a draped female figure used as an architectural support instead of a column – exhibiting the effects of pollution at the Acropolis in Athens, Greece.



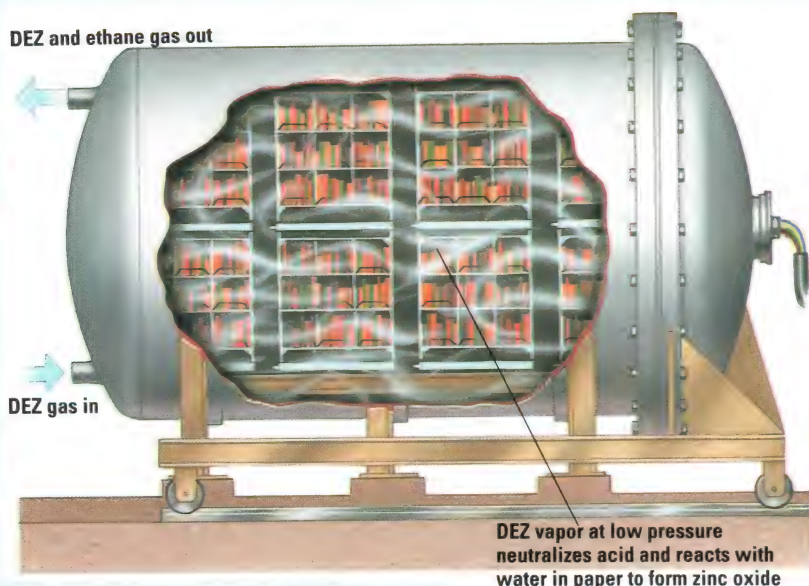
Changing humidity is the main cause of the cracks in this painting by James Seymour. They are made more pronounced (above) by photographing using 'raking light' to show underlying defects.

ways to do this is with substances known as organic monomers or pre-polymers. These are introduced into the stone, then made to polymerize, or join into long molecular chains, by

paper that was introduced in the middle of the last century. In this process wood pulp became the main source of the cellulose from which paper was made, replacing the cotton

Dept, Tate Gallery, London

Akzo Chemicals/Paul Williams



Deacidification is a process of treating books with diethyl zinc gas (DEZ) to preserve them by neutralizing the acids in paper that make books decay. DEZ changes acids present to neutral salts.

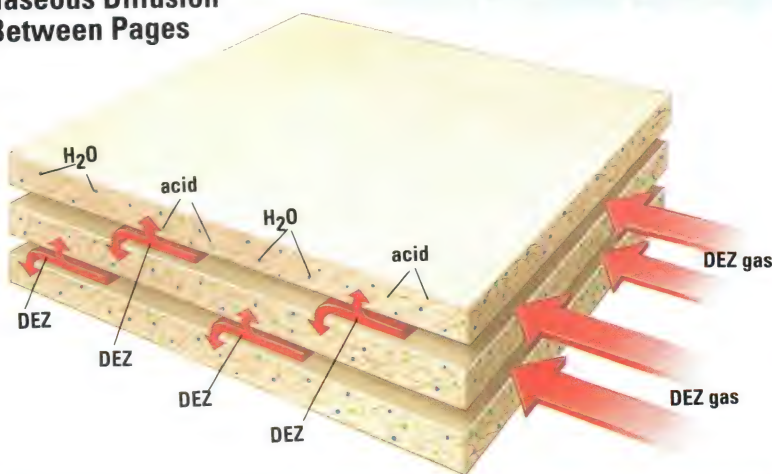
Books to be treated are placed in a closed chamber and the air is removed to produce a vacuum. Water, normally present in paper, is reduced by the vacuum and slight heating. The DEZ gas is then introduced into the chamber and allowed to remain until existing acids have been neutralized. The neutralizing occurs because DEZ reacts with acid molecules to form zinc sulphate and ethane gas. Zinc oxide is formed by the reaction of the gas with residual water, and this neutralizes any acids that may form in the future.

This process takes about 60 hours and increases the life of the paper up to five times. The cost per book is £2, a substantial saving compared to micro-filming, which costs £40 per book.

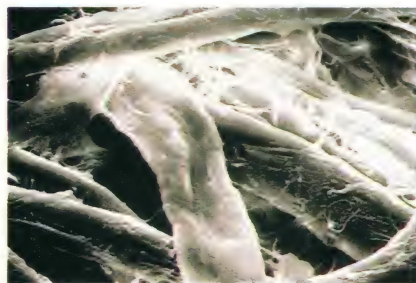
binding and will need to be rebound.

Two new methods of preserving books are a process called deacidification, developed by the chemical company Akzo in conjunction with the Library of Congress, and a system

Gaseous Diffusion Between Pages



Filter paper before treatment with the paper-strengthening process being developed at the British Library, London, UK. The fibres are clearly visible.



Polymer deposits have coated the individual paper fibres after the strengthening process has been carried out. Polymer is also stretched between paper fibres.

A security system for the protection of artworks. The screen shows an X-ray reading of a coded implant inserted in the painting, details of which are kept in a strongroom in Geneva.

currently being researched at the British Library. Deacidification is mainly for preventing the decomposition of contemporary books as it does not restore the strength of damaged paper and is therefore only suitable for books that retain enough strength. This system, using a gas, aims to eliminate the acid content of the paper and to deposit an alkaline buffer against future attack (see LIFE SAVER above).

The method being researched by scientists at the British Library on the other hand, as well as treating paper to retard degradation, restores some strength. A polymer is deposited within the underlying mesh of the paper, so helping to strengthen and protect the individual fibres. A polymer is a substance with very large molecules, which are built up from a series of small basic units (monomers).

A monomer mixture is introduced into a container holding the books. The container is then irradiated with a low dosage of gamma rays, which convert the monomers into polymers. Individual paper fibres are coated with polymer and polymer is also stretched between paper fibres. The books are thus protected against acid attack and also strengthened without adding significant bulk.

GLOBAL GARBAGE CRISIS

EVERY CITY OF THE WORLD IS overrun with rubbish. So much is produced that it is almost impossible to get rid of it all. There are just not enough places to bury it.

In some places better use is made of this domestic waste by burning it and using the heat produced to generate electricity. Incinerating rubbish in special plants costs £20 a tonne compared with £15 a tonne to bury it. But the electricity generated is worth £10 – giving a profit of £5 a tonne. It is estimated that if all domestic garbage were handled this way it would provide 10 per cent of electricity needs. However, simply by extracting the glass from one tonne of domestic waste and taking it to the bottle bank saves more energy. Added to that the fact that some domestic waste is



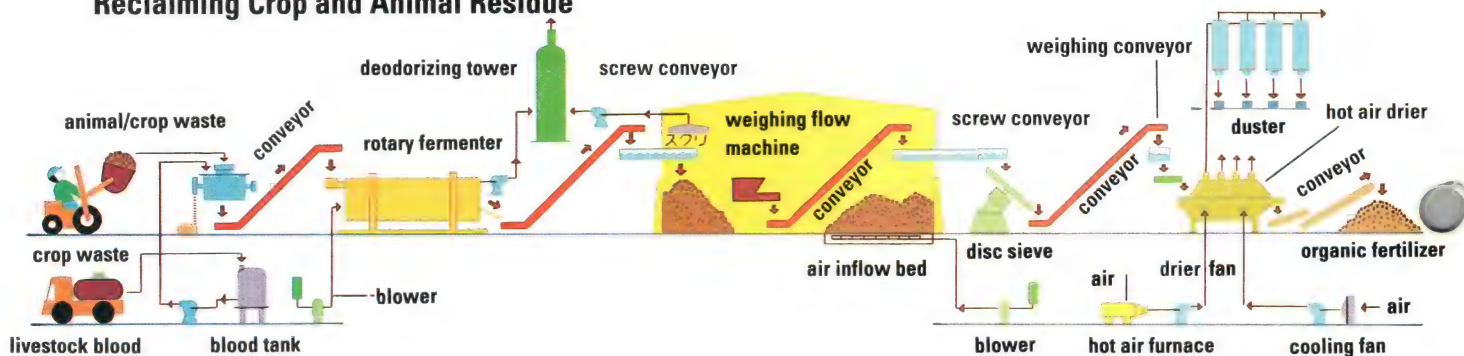
Huge amounts of energy are wasted if scrap metal is not recycled. Making one tonne of aluminium from ore, for example, uses enough energy to recycle 20 tonnes of scrap aluminium.



Landfill is no solution. Most cities are quickly running out of sites and the organic matter in buried rubbish creates methane – a powerful greenhouse gas.



Reclaiming Crop and Animal Residue



found to give off the cancer-causing chemical dioxin when burnt, it seems that recycling is the real answer to the global garbage crisis.

To make one tonne of paper, it takes the wood from 17 trees, 5,000 kilowatt-hours of energy and 130,000 litres of water. The trees

alone take 55 years to mature. All that goes to waste if it is thrown away.

But if the paper is recycled, to make one tonne of new paper, the wood from only one or two new trees is needed to add new fibre for strength. Only 1,100 kilowatt-hours of energy and 130,000 litres of water are needed. This is a great saving. However, only 25 per cent of the world's paper is recycled.

Paper exchange

In many parts of the world, paper is collected separately from other household garbage. In Tokyo, for example, you cannot buy toilet rolls – you have to hand in your old newspa-

Crop waste is reclaimed by mixing it with livestock blood and other slaughter-house waste. The mixture is then fermented, dried and, after the removal of rough lumps, it is used as an organic fertilizer.

1989, on two kilometres of beach on an uninhabited island in the Outer Hebrides off Scotland, over 100 plastic objects were found – half of them plastic containers. In the middle of the Pacific Ocean, over 900 km from the nearest civilization and outside the main shipping lanes, over three plastic items an hour were found floating.

A recent survey found that one in

Clean Japan Centre/Andrew Shaw



James Holmes/Science Photo Library

New bags from old. Clear new polythene is extruded from recycled waste. Old polythene is processed into pellets which are soaked in hot water, then blown out into a plastic tube by hot air.

Crushed glass from bottle banks is used as cullet, a fluxing agent used to help melt the raw materials when making glass. Adding cullet reduces the amount of energy required. But the glass must be pure – free of stones or foreign bodies.



United Glass Ltd

Just amazing!

HIGH-RISE RUBBISH

IN THE UNITED STATES, THE AVERAGE CITY DWELLER DISPOSES OF WELL OVER A TONNE OF DOMESTIC GARBAGE EVERY YEAR.



Paul Raymond

pers to get toilet rolls in exchange.

Every year over 150,000 tonnes of car tyres – made from synthetic rubber – are thrown away, and the energy used to make them is lost. On top of that, the 400,000 tonnes of man-made plastics and more than 175,000 tonnes of cellulose-based plastics that are used to make clothes, carpets, upholstery, and other synthetic fibres are thrown away every year. Only one-tenth is reclaimed.

Synthetic rubber and plastics cannot be burnt without creating noxious gases, and they are not very 'biodegradable' – left out in the environment, they do not break down. In

five plastic objects found on the coast was over five years old – though none was over 14 years old, giving hope that, in time, plastics do break down.

Choked to death

Still, in their lifetime, plastics can cause devastation. In 1977, a joint American and Russian report found that some 8,000 fur seals were fatally affected by waste plastics. They died slowly from starvation, strangulation, drowning or infection. Similarly, cows, sheep and horses have all died after eating plastic bags. An elephant in Munich Zoo has choked to death on a plastic cup thrown into an enclosure.

NUCLEAR POWER

The nuclear power station at Oldbury, in Gloucestershire, UK, generates electricity and supplies Britain's national grid throughout the day and night.



THE AWESOME ENERGY unleashed by a nuclear bomb can destroy a city within seconds. But nuclear energy can also be released gradually for peaceful purposes – to supply us with electricity and propel ships and submarines.

All atoms consist of a relatively heavy nucleus surrounded by a cloud of tiny, negatively charged electrons. The nucleus is made up of positively charged protons and electrically neutral neutrons, which are bound together by powerful nuclear forces. As a result, most types of nuclei are stable and extremely hard to split apart. But this is not the case with the nuclei of some very heavy atoms.



Uranium-235

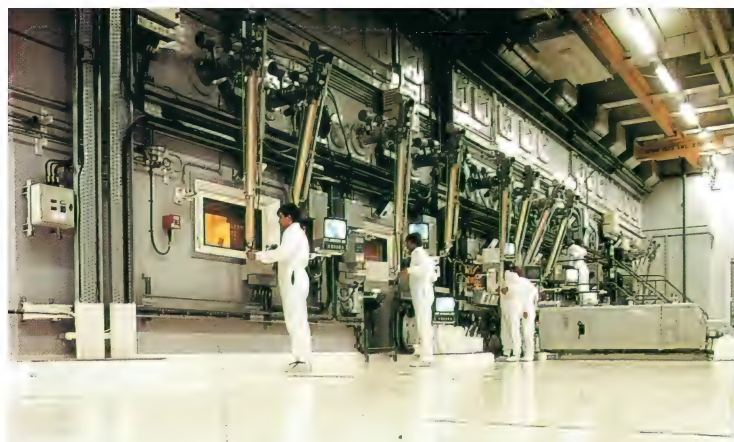
An engineer checks equipment inside a nuclear power station. Some of the pipes convey a liquid or gas, which transfers heat from the reactor to the station's steam generating stages.

Uranium is the heaviest naturally occurring element on Earth. Most uranium is of a type called U 238. The nuclei contain 92 protons and 146 neutrons. Nuclei of U 238 are difficult to split apart artificially. But about one in a hundred atoms of natural uranium are of a different type: U 235.

If a particle such as a neutron collides with a nucleus of U 235, the nucleus may shatter into two large

Martin Bond/Science Photo Library





Health hazards can result from overexposure to radioactive materials. So workers in the nuclear fuels industry handle the specially screened materials by remote control.

NUCLEAR ENERGY

Country	Electricity from nuclear energy
France	70%
Belgium	67%
Sweden	50%
Switzerland	39%
Germany	30%
Spain	29%
Japan	25%

fragments plus a number of smaller, fast-moving particles. Among these released particles are neutrons that can then go on to split apart other U-235 nuclei, and so on. The splitting apart of a nucleus is known as fission, and the process by which fresh particles cause further fission is called a chain reaction.

Controlling a chain reaction is all-important. If the chain reaction in a lump of uranium gets out of control, the result is a devastating explosion. On the other hand, if the U-235 nuclei are spread too thinly, it may be impossible even to start a chain reaction.



Fuel elements

In most reactors, the concentration of U-235 is boosted from about one per cent, as it occurs in nature, to about three per cent. The enriched uranium, usually in the form of uranium dioxide, is loaded into narrow tubes, called pins, measuring several metres long. Up to 200 pins are mounted side-by-side to form a cylindrical fuel element, ready to feed into the reactor.

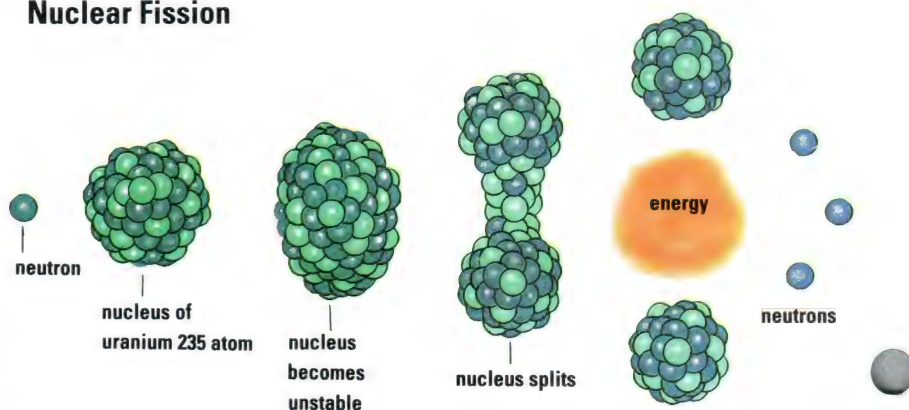
The chain reaction is started by bombarding the fuel elements with neutrons. The reaction is kept at the right level by controlling the flow of

they bump into other U-235 nuclei. The moderator surrounds the fuel elements in the reactor core.

To alter the rate of the chain reaction, control rods are pushed in or out of the core. These rods, made of a neutron-absorbing material, soak up

Two different designs make up the bulk of reactors currently in use. The advanced gas-cooled reactor (AGR), popular in the UK, employs a gas coolant and a graphite moderator. In the pressurized water reactor (PWR), water serves as both the coolant and moderator. Because the water is kept

Nuclear Fission



Nuclear fission, or splitting, of a uranium-235 atom starts when it is struck by a neutron. The atom becomes unstable and then splits, releasing energy and more neutrons.

Electronic control and monitoring play a major part in the operation of a nuclear power station. The equipment enables engineers to keep a continuous check on all processes.



THE HYDROGEN BOMB

Nuclear energy can be used for peace or for the most deadly of all purposes – nuclear war. Atomic bombs – the first nuclear weapons – worked by setting off an uncontrolled fission (splitting) reaction in a small mass of uranium. Nuclear weapons today, however, rely on the even more awesome power of nuclear fusion – the smashing together of lighter nuclei to make heavier ones. In this process, which usually involves hydrogen nuclei fusing to form helium nuclei, a tremendous amount of energy is released. But to trigger the fusion reaction, temperatures as high as 100,000,000°C are required. An atomic bomb trigger provides the sudden injection of heat required to set off the nuclear fusion reaction.

free neutrons. When a U-235 nucleus breaks up, the neutrons that escape are travelling very fast. These have to be slowed down by a material called a moderator so that they have a better chance of causing fission when

neutrons and so reduce the number available for causing fission.

As the fast-moving neutrons produced by U-235 fission split other nuclei inside a fuel element, a great deal of heat is produced. This heat is carried away by a coolant that is pumped through a gap between the fuel element and the moderator. If the flow of coolant were to stop, the fuel elements would quickly overheat and turn to liquid – a dangerous condition known as 'melt-down'.

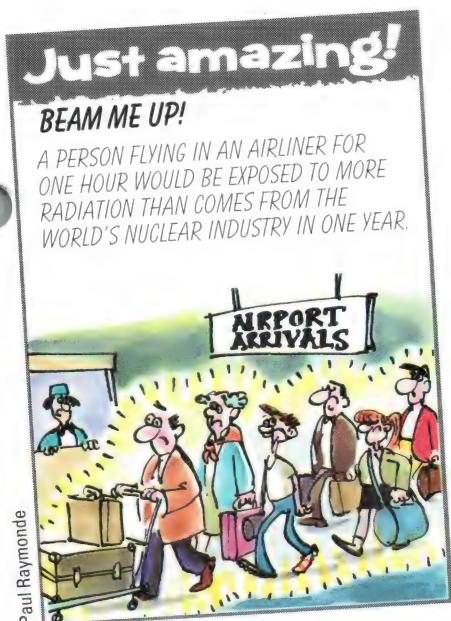
at a very high pressure inside a thick-walled steel vessel, it does not boil, even though its temperature rises to about 300°C.



Steam turbine

In both types of reactor, the coolant then passes through a heat exchanger, where its heat is used to turn water into steam. The steam drives a turbine, which spins a generator to produce electricity.

After several years in a reactor, the



U-235 in the fuel becomes exhausted and has to be replaced. But the spent fuel elements are not wasted. They go to a reprocessing plant, such as the one at Sellafield in Cumbria, UK, where useful uranium and plutonium are extracted. The plutonium is

This pressurized water reactor uses high-pressure water to transfer heat from the reactor core to four steam generators. The steam drives turbines.

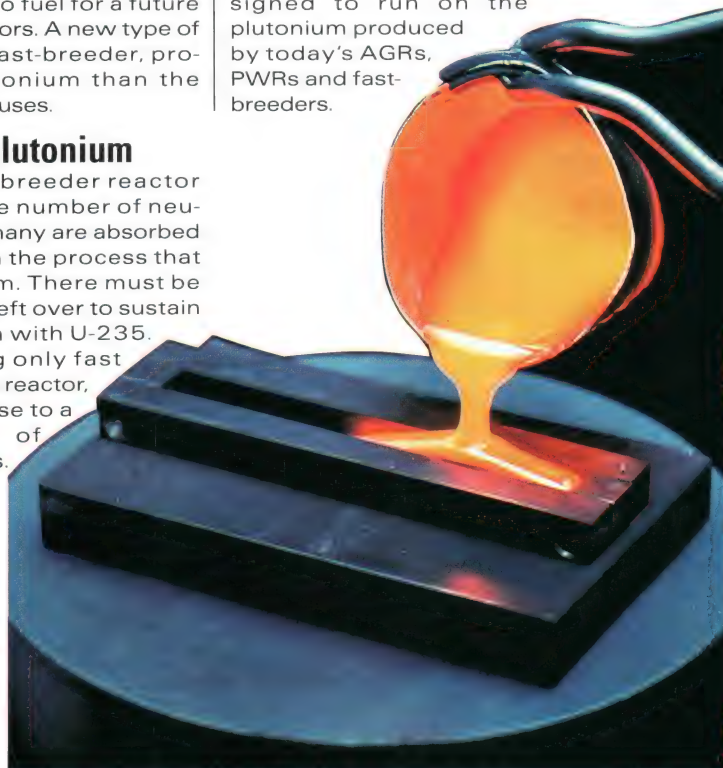
produced when neutrons inside the reactor collide with the non-fissile form of uranium, U-238.

Plutonium is used in nuclear weapons. So some of the plutonium from reprocessing plants goes to supply the defence industry. The rest is stored or made into fuel for a future generation of reactors. A new type of reactor, called a fast-breeder, produces more plutonium than the amount of U-235 it uses.

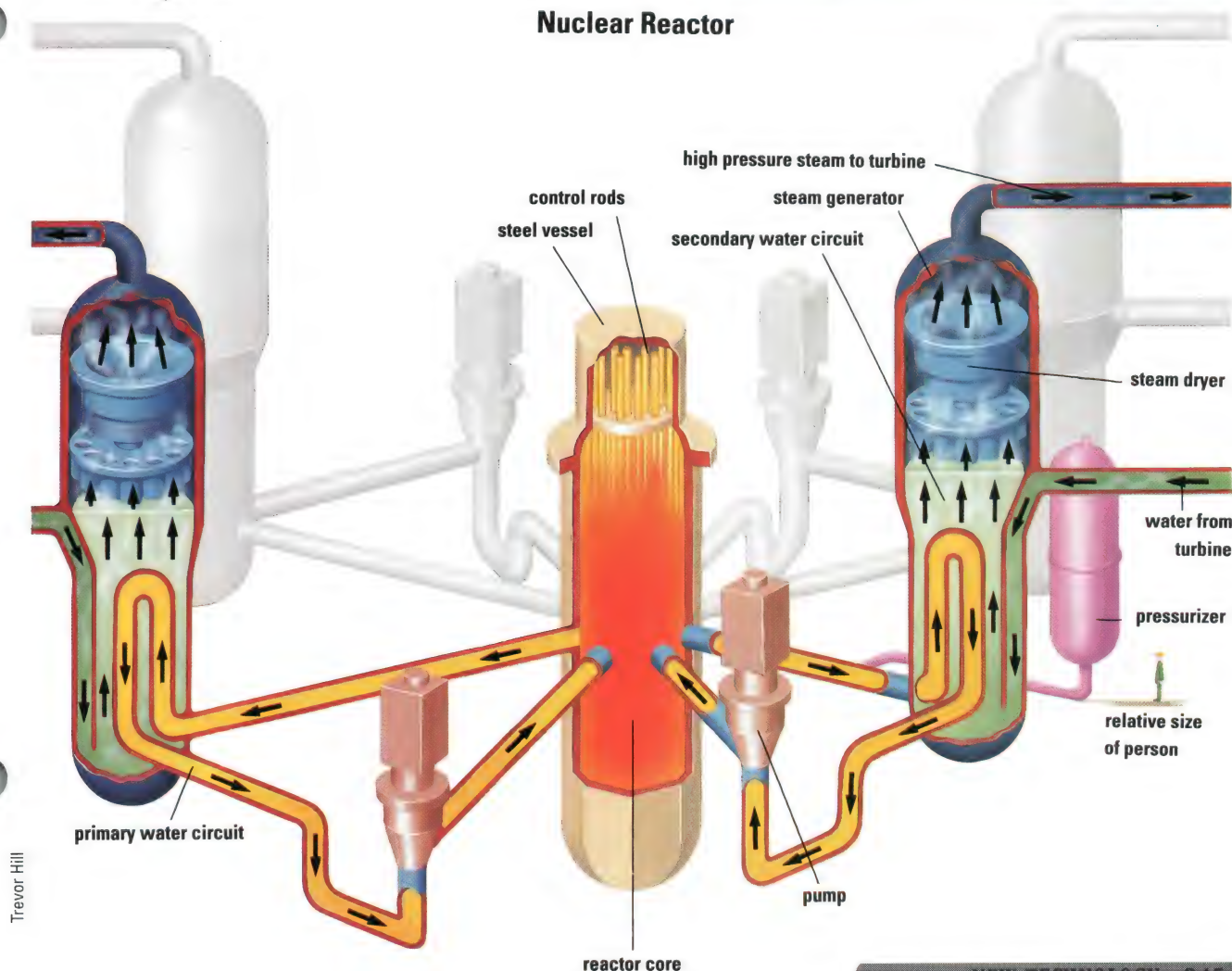
Breeding plutonium

To keep going, a breeder reactor needs a very large number of neutrons because so many are absorbed by U-238 nuclei in the process that 'breeds' plutonium. There must be enough neutrons left over to sustain the chain reaction with U-235. This means using only fast neutrons inside the reactor, since these give rise to a greater number of fresh fast neutrons.

Molten glass containing nuclear waste being poured into a mould. When solid, it is relatively safe for disposal as the glass prevents water leaching out the radioactive materials.



Nuclear Reactor



US Dept of Energy/SPL

Trevor Hill



NASA/SPL



The **Galileo probe** left the Space Shuttle in October 1989. Nuclear generators power the probe as it continues its six-year journey to the planet Jupiter.

Frank Morgan/SPL



A **geiger counter** being used to check the level of contamination by radioactive materials in a research laboratory.

The **H-bomb** is powered by nuclear fusion. Energy is released when hydrogen isotopes, deuterium and tritium, join together.

O. Seibert/Jefferson

Nuclear radiation affects all living things. It forces cells to mutate genetically, producing new species. The effects are studied in the laboratory.



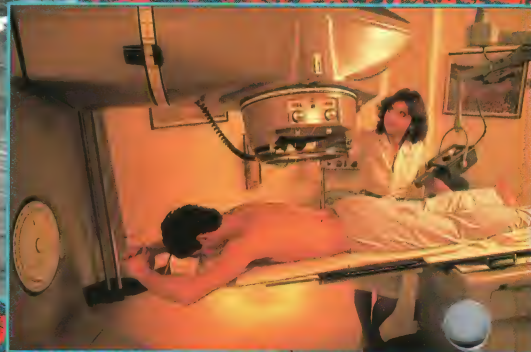
An aircraft carrier powered by two nuclear generators. This ship, **USS Nimitz**, can stay at sea for up to 13 years without having to refuel.

Radioisotope cobalt-60 is the source of gamma rays used to treat this patient for cancer of the spine. Laser beams help aim the radiation at the target area.

Martin Dorn/SPL



TRH Pictures/DOO/USAF



The first nuclear submarine in commercial use was the **Saga 1**, developed by Henri Delauze (right). The actual vessel is behind the cutaway model.

Box Features



EMERGENCY



Swift action by ambulance teams can mean the difference between life and death for accident victims. Here, oxygen is administered to the victim of a road accident.

A MAN COLLAPSES ON THE street, gasping for breath and clutching at his chest – the victim of a massive heart attack. Within minutes he might suffer irreversible brain damage and die. But help is on the way. A well-equipped ambulance and crew will keep him alive until he arrives at a hospital emergency room.

No medical emergency is more dramatic or urgent than a sudden heart attack, or cardiac arrest. All at once, a person's heart stops beating properly and the flow of blood to the brain is cut off. The victim loses consciousness and ceases to breathe or show a pulse. Only immediate treatment to restart the heart can then save the individual's life.



Dangerous delay

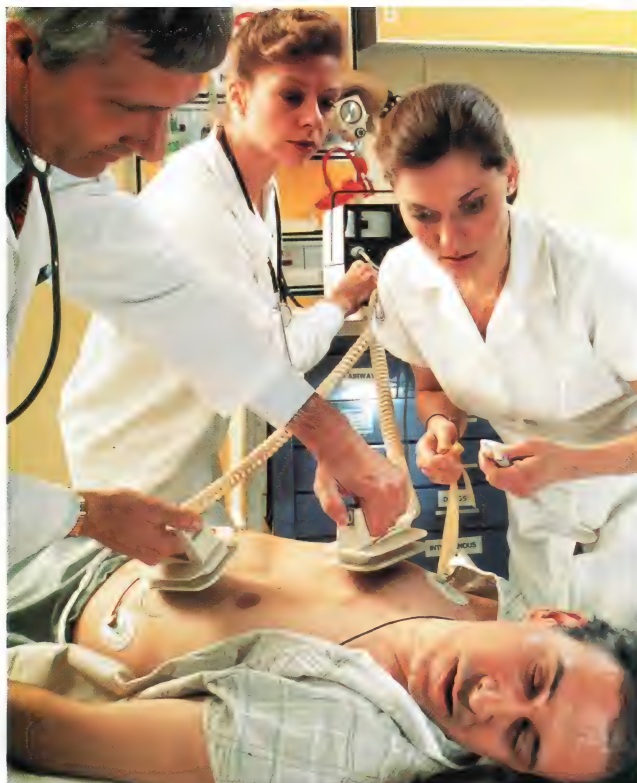
Even the short delay in getting a heart attack victim to hospital may be too long. For this reason, ambulance crews are trained in two basic meth-

ods of revival. The first is a manual technique known as CPR, or cardiopulmonary resuscitation. This involves the medic breathing into the patient's mouth – the 'kiss of life' – and pressing on the chest repeatedly to get oxygen as quickly as possible to

the brain, heart, and other vital organs. Following successful CPR, a special tube is inserted into the trachea, or windpipe, to keep the vital air passage open to the lungs.

If the heart is still not functioning, the emergency crew apply a defibrilla-





tor. This consists of two metal plates with insulating handles that can deliver a brief but powerful electric shock across the patient's chest. The sudden shock interrupts the random twitching of the heart muscle and gives the heart a chance to resume its normal electrical activity.

Fatal shock

The difficulty is that many heart attacks occur at home, where no expert is on hand to work an ordinary defibrillator. If not applied properly, these devices will fail to restart the heart – and worse, they can give the operator a fatal shock.

Newly developed automatic defibrillators may soon change the situation, however. The rescuer simply attaches adhesive electrodes to the victim's chest, and the automatic defibrillator does the rest. Pro-

A defibrillator has many different features to help monitor its use.

It shows, for example, whether the paddles have made proper contact with the patient's chest, and the central screen shows the patient's heart rate.

A cardiac arrest patient is given emergency treatment in hospital. The two paddles, or plates, of a defibrillator are applied to his chest. These transmit an electric shock, which will give the heart a chance to start beating normally again.

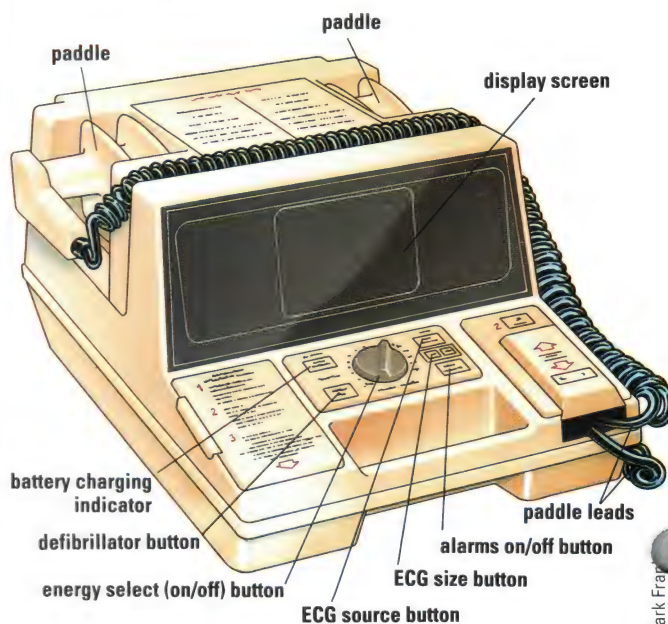
sends out a series of electrical pulses through fine wires leading to the heart over a 15- to 20-second period.

Changing batteries

Since the pulses do not have to pass through the chest wall, they need to have only about one-fifteenth the energy of a normal defibrillator shock. The power source for the implant is a lithium battery that lasts about three years and can be replaced at regular intervals by a minor operation.

Doctors fighting to save the life of a critically ill or injured person need

Defibrillator



Mark Fra

RESUSCITATION

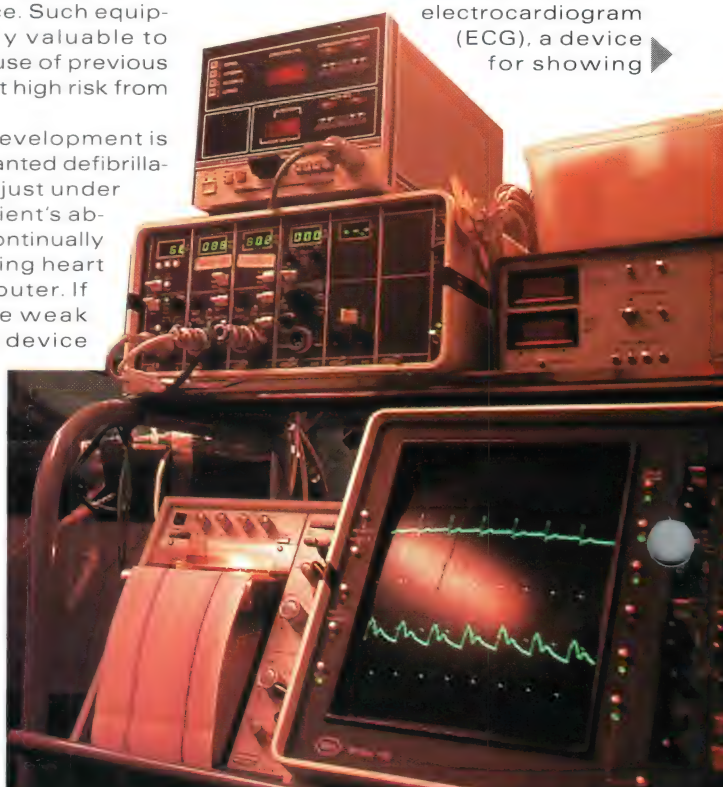
Cardiopulmonary resuscitation, or CPR, is used when someone shows no signs of breathing or having a pulse. First, the head is tilted back to open a clear passage to the lungs. Then, the rescuer pinches the patient's nostrils, seals his mouth over the patient's mouth, and blows. After two breaths, about five seconds apart, the pulse is checked. If there is no pulse, the rescuer thumps the patient's chest with a clenched fist. This simple action can have the same effect as an electric shock starting the heart off again. If this is unsuccessful, the rescuer places the heel of one hand over the patient's breastbone, covers it with the other hand and applies pressure about 15 times in succession. Then the rescuer delivers two more breaths, followed by another set of chest compressions, and so on, until the patient successfully revives.

grammed to detect the condition of the heart, it decides whether to administer a shock, where this should be directed, and how powerful it should be. A synthesized voice or liquid-crystal-display messages help the rescuer to set up the device. Such equipment is especially valuable to people who, because of previous heart trouble, are at high risk from heart attack.

Another new development is the surgically implanted defibrillator. This is placed just under the skin of the patient's abdomen, where it continually monitors the beating heart with a microcomputer. If the beats become weak and irregular, the device

continually to monitor the patient's breathing and heart condition. Instruments that automatically display breathing rate, blood pressure, and heart rate have been available for some time. Also, the electrocardiogram (ECG), a device for showing

In the operating theatre, an electrocardiograph monitors how the patient's heart is working, showing the information on screen and as a print-out. Above the screen are digital read-outs for blood pressure and pulse rate.



the electrical activity of the heart, is a familiar sight in hospital emergency and recovery rooms.

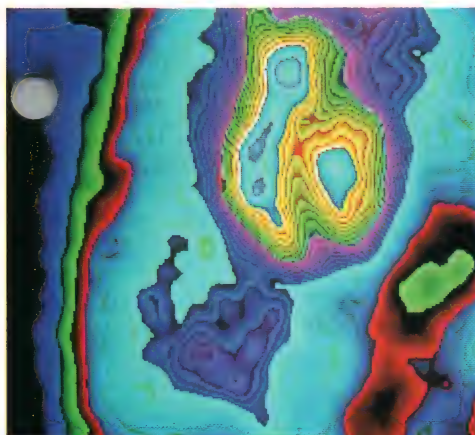
The ECG works by sensing the tiny electrical currents produced by muscles in the heart. These are transmitted to the machine through wires from a dozen electrodes, which are moistened with conductive paste and fixed to the arms, legs and chest. The ECG then amplifies the currents about 3,000 times and traces the pattern of heart waves on a strip of moving paper or a screen.

ECG alarm

Patients who are recovering from a heart attack or coronary surgery are connected to an ECG in the recovery room. If the device senses that the heart is behaving abnormally, it instantly sounds an alarm at the nearest nurses' station for emergency help.

One of the latest monitoring devices is the niroscope. It can show within two to three seconds whether the brain is receiving sufficient oxy-

The activity of the human heart can be monitored by the gamma camera. This gamma camera picture shows the heart during diastole, the period between contractions when the heart fills with blood.



Alexander Tsiras/SPL

gen. Such a warning may be crucial, for example, while the patient is under anaesthetic – starved of oxygen for just three minutes, the brain would be permanently damaged.

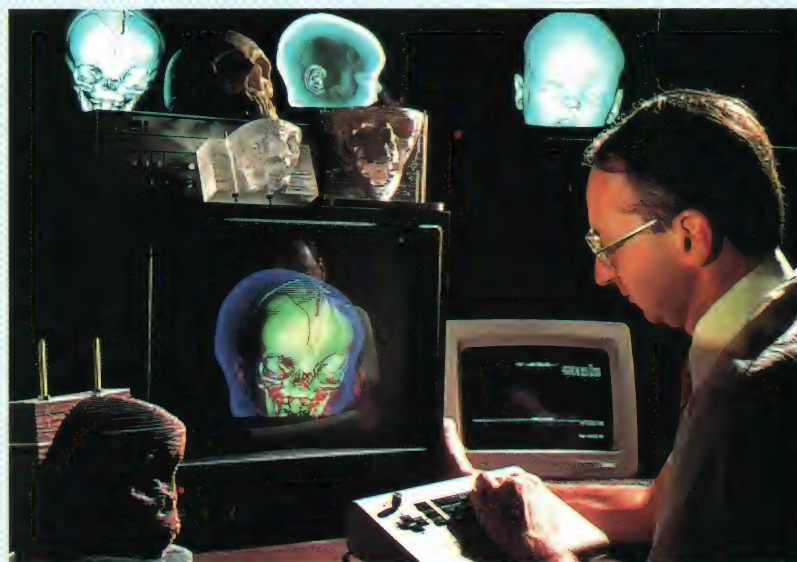
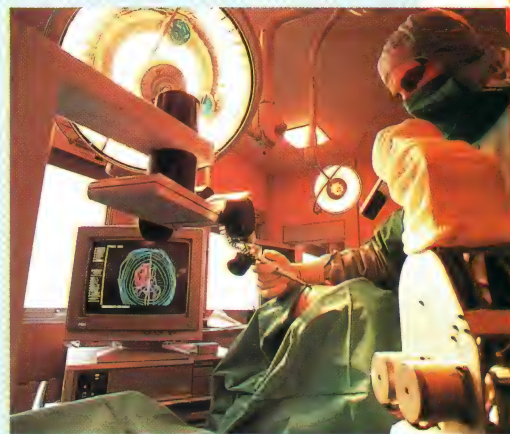
Oxygen starvation

The niroscope works by shining infrared light of different wavelengths through the skull into the brain and measuring how much of that light is reflected back out again. The brain's tissue changes its absorption of infrared light depending on the amount

Nuclear cardiology, involving the gamma camera, is especially useful in checking damage to the heart muscle after an attack and in monitoring blood flow. A single sodium iodide crystal picks up radiation from the heart, and this is then transformed into a picture.

COMPUTERIZED BRAIN SURGERY

Some of the most difficult and delicate surgery of all has to be carried out on the brain. Brain surgeons may soon have access to a computerized system that allows them to see an image of a patient's brain before they operate. This system lets doctors draw their incision on a video picture of the patient's skull, then press a button to see the underlying folds of the brain. Another program allows them to view a slice through the brain at the point exposed to check, for example, whether a tumour they want to remove is underneath. The new computer system uses data collected by a method called magnetic resonance scanning.



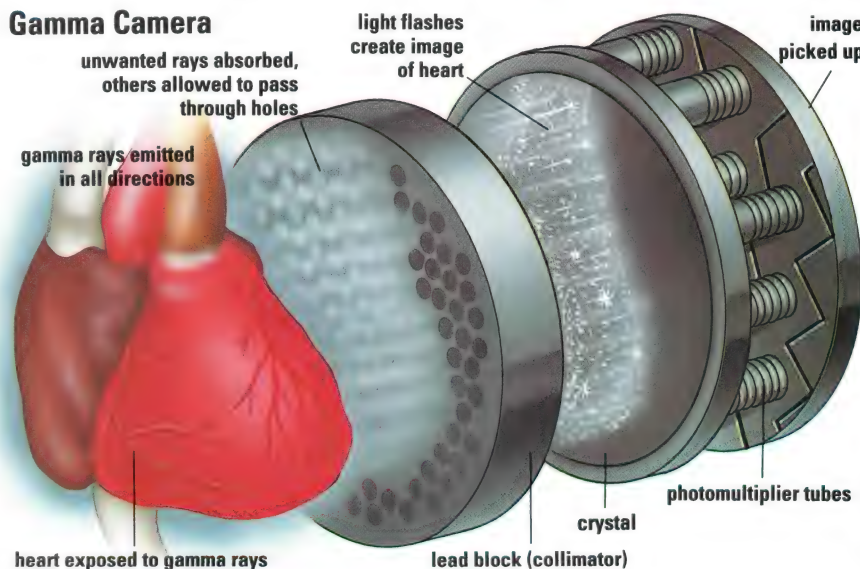
Philippe Plailly/Science Photo Library

of oxygen available to the nerve cells.

Another valuable new monitoring tool is the echocardiogram. This works by recording the echoes of ultrasonic waves – very high-frequency sound waves – from various parts of the heart. The results can show blood clots, faulty valves and other abnormalities of the heart that might otherwise escape detection.

The most recent development of this technique involves the use of a tiny sound transmitter that provides an even clearer image of the beating heart. The device is located at the tip of a long, flexible probe that is passed down the throat of the anaesthetized patient. By altering the angle and position of the probe, the doctor can accurately direct ultrasound waves at

Gamma Camera



Mark Franklin





Military field hospitals are vital to help wounded troops survive. Emergency surgery performed by combat-trained surgeons directly after a soldier has been injured can make the difference between life and death.

Other identification methods include mass spectrometry. Using this method, the chemical formula of the poison is worked out by measuring the numbers of different atoms in a blood sample.

Washing the stomach

Treatment then follows immediately. One of the simplest procedures is gastric lavage, or washing out of the stomach with warm water. However, this does not usually work if over four hours have passed since the poison



A doctor examines a nine-day-old baby, kept alive on a ventilator. After premature delivery by caesarian section, the baby was given an emergency operation on its small intestine.

S Fraser/Dept of Child Health, RVI, Newcastle/SPL

a particular portion of the heart. An image of that section of beating muscle then appears on a video screen.



Accidental death

While some emergencies are caused by natural disorders of the body, others come about through accidents. Poisoning, for instance, is one of the commonest causes of accidental death, along with car accidents, drowning and burns. Increasingly, though, poison victims are being saved by new, faster methods of identifying the chemicals swallowed and then removing them.



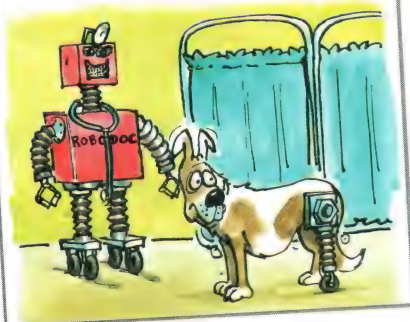
A pacemaker, or pulse generator, is implanted in a patient's chest. This is connected to a lead threaded through a vein into the heart. The pacemaker then sends an electrical impulse down the lead to regulate the heartbeat.

John Watney Photo Library

Just amazing!

ROBODOC

A SURGICAL ROBOT, 'ROBODOC', HAS CARRIED OUT ITS FIRST OPERATION IN THE US - PREPARING A DOG'S LEG BONE FOR AN ARTIFICIAL JOINT.



Paul Raymond

The treatment for poisoning depends on the substance involved. If this is unknown - as is often the case with young children - then tests have first to be carried out. The latest of these is EMIT (enzyme multiplied immunoassay technique). This relies on the fact that chemicals called antibodies will attach themselves to molecules of a particular drug,

was swallowed. Then, a more advanced technique such as haemoperfusion may be used instead. Haemoperfusion involves passing the patient's blood through a column containing charcoal coated with a substance called acrylic hydrogel. During the process, the charcoal forms chemical bonds with the poison and so removes it from the blood.



FROSTBITE

HYPOTHERMIA

CLOTHING

TO THE ENDS OF THE EARTH

EXPEDITIONS TO THE POLES and to the summits of high mountains face incredible hardships. Yet their success is made more likely by an array of modern technology.

The harshest frontiers on Earth are the frozen regions north of the Arctic Circle – an imaginary line at 66°31' N – and regions of the south polar continent of Antarctica. Here, the temperature can plunge as low as -70°C while fierce winds lash bare

Modern-day polar explorers use skidoos and other mechanical means to get about on the ice cap. But extreme cold is still a problem. Water vapour given off by the body can freeze inside clothes (right), drastically cutting their insulating properties.

skin with icy snowflakes. Naked, exposed to -40°C temperatures and 44 km/h winds – conditions common in the Arctic winter – a man or woman would have a life expectancy of about 15 minutes.



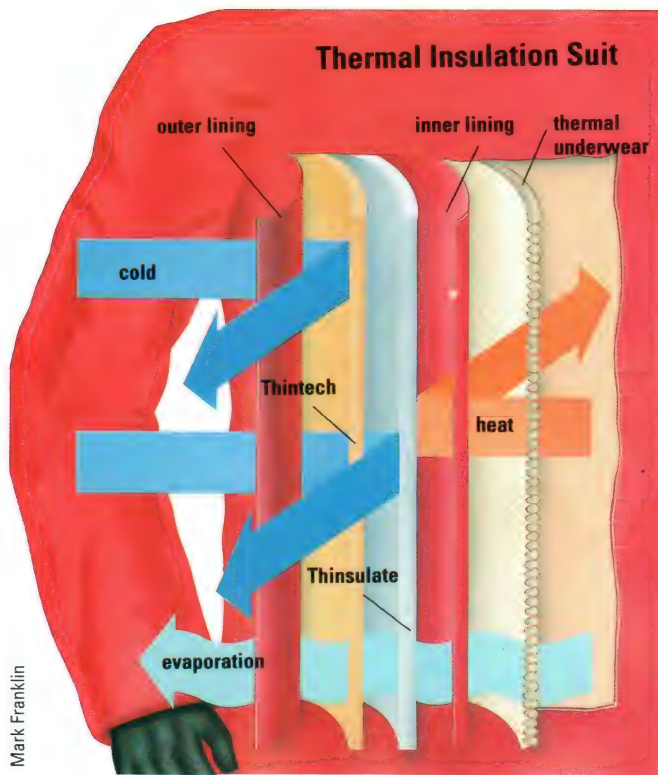
Bare flesh

Polar survival depends on retaining body heat. At -35°C bare flesh freezes within about one minute. Keeping warm is made especially difficult by windchill – when a strong



Westward Ho Adventure Holidays Ltd





Mark Franklin

Thermal underwear traps an insulating layer of air in thin ridges. Outer layers of Thinsulate trap air in a boundary layer against the fibres. Thintech keeps out wind and water.

An old-fashioned sled and huskies still come in useful in polar regions. Although modern snowmobiles can travel efficiently across the icy wastes, engines can freeze up.

air spaces, causing the clothing to lose warmth.

For this reason, polar travellers today prefer to wear synthetic clothing. Composed of polyester or polyolefin fibres, these absorb almost no water but instead carry it away from the skin to the outer surface of the clothing. Synthetics, such as Du Pont's Hollofil and 3M's Thinsulate, also have the advantage of retaining 'loft'. That is, they continue to trap air when wet, and dry rapidly even in freezing temperatures.



Underwear

Layered clothing provides far better insulation than just one or two heavy garments. A carefully chosen combination of underwear, pants, vest sweater, parka and mittens keeps



Sverre Arseth/Royal Geographical Society

wind brings the effective temperature down to dangerous levels. A low air temperature combined with gale-force winds can quickly lead to two potentially threatening conditions. The first is frostbite, which starts with a loss of feeling in the fingertips, toes and parts of the face. The affected

Hot food and a warm sleeping bag are vital, even when stopping to check the course. Getting lost or cold means just one thing – death.



Roger Mear/Royal Geographical Society

captured moisture to a minimum while trapping as much warm air as possible. Finally, a woollen hat plus fur-lined hood is indispensable. Below -40°C , more than half of a person's body heat could escape from an uncovered head.



Danger to life

Because of the danger to life posed by extreme cold, shelter is second only to first aid in a survival situation in mountains and cold regions. Polar tents are generally small so there is less volume to heat and of a low, curved profile to deflect strong winds. Inside, high loft sleeping bags of down, or down mixed with polyester,

WORST WEATHER

With a summit at 1,916 metres, Mount Washington in New Hampshire is dwarfed by 8,840-metre-high Mount Everest. Yet, it is exposed to the powerful prevailing winds in this region and also lies at the meeting point of three storm tracks. As a result, Mount Washington is home to some of the world's most severe weather. Winds reach hurricane force about every third day, and the highest straight-line wind speed on Earth was recorded here at 372 km/h. Many who have attempted to climb it improperly equipped have met with frostbite, hypothermia and death.

skin turns red, then white and finally grey as the blood circulation stops.

Even more deadly is hypothermia, the first symptoms of which are shivering and drowsiness. Hypothermia happens when the body's core, or internal, temperature begins to fall. If it drops even two degrees below normal, the victim may die.

Proper clothing is essential. It has

to insulate a person's body by trapping pockets of warm air next to the skin. This calls for a fabric whose microscopic fibres have a relatively large amount of surface area, in order to trap more air.

In the past, down from young birds was a popular insulating material. But as down becomes wet, through perspiration, it mats. This squashes the



help provide personal warmth. Some expeditions, however, travel without sleeping bags to save weight. By relying on their insulated polar suits to keep them warm by night as well as by day, team members are also better equipped to survive if an ice crack opens up underneath a tent and they fall down it.

All Terrain Cycle

Getting around on the polar ice can be achieved in several ways: on foot using skis, by dog sled, by snowmobile, or by All Terrain Cycle (ATC). An ATC is a motorized tricycle with balloon tyres, which help absorb bumps and stop the vehicle from sinking into soft ground or slipping on ice.

To travel quickly and safely to remote parts of the Arctic or Antarctic, small aircraft are most useful. They can also carry food, baggage and scientific equipment – everything the scientific teams need to survive and work – in large quantities to polar re-

other hand, have the ability to land on even smaller patches of ground but are more limited in their range.

Travelling by foot is particularly hazardous in the Arctic, where leads, or open stretches of near-freezing water, can suddenly open up in the pack ice.

In spite of the low temperatures, winter is the best time to make good progress. Even then, however, there are obstacles called pressure ridges that form when massive blocks of

still last until the end of the journey.

The average distance from the tree line of the Arctic to the North Pole is 2,300 km. In all that distance, there is little chance of finding anyone who can help if an expedition runs into difficulties. As a result, radio contact is a vital communications link.

Search and rescue

In the Canadian Arctic, for instance, explorers are required to contact a base station twice a day, at 7 am and



Beedell/Sipa/Rex Features



The Antarctic is now the home of vital environmental research. This balloon is being sent up to sample the ozone layer. A hole in the ozone layer over the South Pole is causing great concern.

7 pm. Failure to radio in three times in succession leads to a search and rescue plane being sent out.

As well as normal radio transmissions, polar travellers can use orbiting satellites to fix their position or send out an S.O.S. message. Some expeditions, however, choose not to employ modern technology but to rely instead upon the simpler technique – navigation by the Sun and stars.

Light planes used in polar regions have their wheels replaced with skis so they can land on soft snow. This plane is landing at Palmer Station, on Grahamland Peninsular, Antarctica.

search stations or members of trans-polar expeditionary teams who are on the ground.

Short take off

The De Havilland Twin Otter, a twin-propeller plane that can land or take off on skis or balloon tyres in distances as short as 200 metres, is especially popular. Helicopters, on the

sea-ice collide and crumple. Together with the unpredictable and hostile weather, this means that expeditions often find themselves running behind schedule – and, worse, begin running out of food.

Whiteout

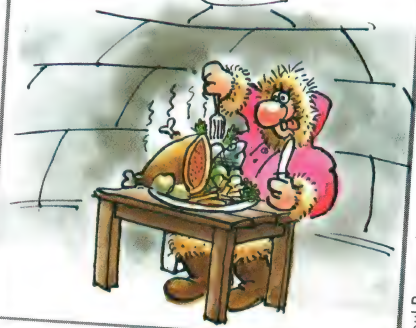
One of the most feared of polar events is the whiteout, caused by a heavy blizzard or low, dense mist. When this happens, the horizon vanishes and every direction appears to be exactly the same.

The only course of action is to hastily set up tents and wait out the storm, hoping that food rations will

Just amazing!

FATTY FOODS

POLAR TRAVELLERS BURN UP SO MUCH ENERGY THAT THEY MUST EAT A DAILY, FAT-LADEN DIET OF ABOUT 7,000 CALORIES – MORE THAN DOUBLE THE AVERAGE MAN'S INTAKE.



Paul Raymond



Gamma/Frank Spooner Pictures



This 'boy in a bubble' only survives because he is completely sealed off from the world. He has no immune system to fight off germs so the smallest cough or the slightest cut in the outside world could kill.

Associated Press



An armed hijacker holds a gun on TWA pilot John Testrake on a hijacked plane in Beirut in June 1985 after demands had been shouted to the authorities. Testrake survived. Many hostages have not been so lucky.

John Cleare/Mountain Camera

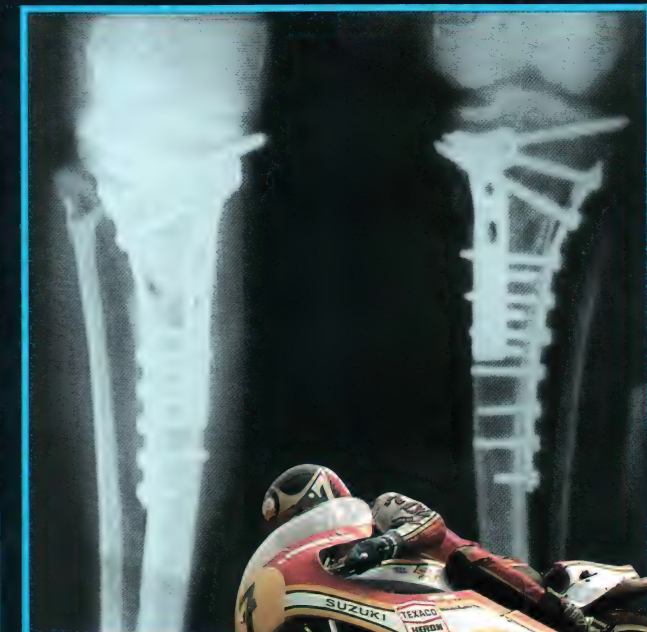


Gamma/Frank Spooner Pictures



An earthquake destroyed 50 per cent of the Algerian city of El Asnam in 1980, killing 20,000. For weeks after, survivors were being pulled from wrecked buildings.

Not many people have been attacked by a Great White Shark and lived to tell the tale. This survivor still bears the marks where the fish held him in its mouth.



Press Association

Rex Features

World motorcycle champion Barry Sheene crashed numerous times. His legs (above) have been bolted back together using stainless steel 'scaffolding'.



- Q HEAT LOSS
- Q RADIO BEACONS
- Q WATER PRESSURE

THE CRUEL SEA

The sea is a hostile environment. The shipwrecked face death by drowning, exposure and dehydration.

The great barracuda is the most vicious of that species. It has long canine teeth for seizing its prey and smaller razor-sharp teeth for tearing its victim to shreds.

Linda Pitkin/Planet Earth Pictures

WHEN MAN CHALLENGES THE sea he faces a hostile and sometimes deadly environment. Survival depends on a variety of specialized equipment and techniques.

Victims of a shipwreck are confronted with several immediate dangers. These include loss of body heat in cold water, drowning through exhaustion or rough seas, and possible attack by sharks. Some basic know-how and emergency gear, however, can mean the difference between life and death.

Being suddenly plunged, or

spending any length of time, in cold water (below 22°C) can lead to immersion hypothermia – a major cause of death in water-related accidents. An object in water loses heat about 24 times faster than in air. In the chilly waters of the North Atlantic, for instance, a person's survival time might be measured in minutes.

Exposure suit

The important thing is to prevent as much heat as possible from leaving the surface of the skin. This can be done by putting on an exposure suit, a head-to-toe, international orange

Tony Stone Photo Library, London



suit that provides buoyancy in the water and insulation against the cold.

A different type of survival suit – a one-piece, zip-up, dry suit, specially developed for use on oil rigs – gives a survival time of 12-15 hours in the North Sea in winter. Movement of any kind has to be restricted to a minimum. If several survivors are in the water, they should huddle together,

This life raft, designed to inflate automatically, has a built-in shelter to protect against spray, breaking waves and wind exposure. Survivors should be secured to the life raft.



Rex Features



enough to cause severe pain, swelling and – worst of all – panic in the victim. A swimmer may then get cramp and lose energy, which may result in drowning. Other stinging marine creatures, like the stonefish and sea urchin, are only a real danger to those walking barefoot on warm, sandy sea beds.

Flotation device

For long periods in the water, some kind of flotation device is essential. A personal flotation device (PFD) is to open ocean survival what a warm sleeping bag is to cold regions survival: a life saver. The most effective

locking arms and legs, to expose less surface area to the cold sea.

Alone, a person would be best advised to use HELP, the Heat Escape Lessening Posture. The aim of this is to protect the body's high heat-loss areas – the head, sides of the torso, and groin. It involves keeping your head out of the water, drawing your arms close to your sides and tucking up your legs to your chest.

Despite their ferocious appearance

Most lifeboat services operate a cover, search and rescue operation in inshore areas – usually within 50 km of the coast. They are assisted by a helicopter rescue service that can winch survivors to safety in seas that are too rough for lifeboats to navigate. Packed lifeboats (right) on a ferry.



Limier/Jerrican



Paul Raymond

and reputation, sharks are more likely to be curious about someone in the water than dangerous. They are especially attracted by blood, splashing movements and bright clothing. However, a sharp poke on the snout is usually enough to send one away if it comes too close. Two-metre-long barracudas can also pose a threat in shallow waters, especially around schools of small fish.

With its long, stinging tentacles, the Portuguese man-of-war jellyfish is to be avoided at all costs. One sting is

tive kind is an inflatable jacket worn around the neck and upper body that is filled with air either by blowing into a valve or by an attached gas canister. This keeps the head above the waves, face back, so that even if the wearer is exhausted or unconscious he or she can continue to breathe.

Better still is a life raft. These are inflated by pressurized gas cylinders and contain a range of survival gear. The onboard kit consists of first aid materials, signalling devices, water, food and navigational equipment.

Sipa/Rex Features



A Diver Propulsion Vehicle (DPV) designed to minimize dive time. It can travel at speeds of up to six knots, and in the event of a mechanical malfunction, the faulty half of the system can be jettisoned, allowing the diver to return to base on the spare.

strapped to the diver's back with a pressure gauge to show how much compressed air remains inside them. At the surface, a single tank will last about 56 minutes. But at greater depths, more and more air is required

FIGHTING THE BENDS

Under high pressure, a diver breathes more air than normal and the extra nitrogen in the air is absorbed into the diver's body. If the diver surfaces too quickly, nitrogen bubbles form in his body causing agonizing pains in bones, joints and muscles. Because of the writhing it causes, this condition is known as the bends. The only way to cure the bends is to quickly put the diver in a decompression chamber. Air is pumped into this at high pressure and then released very slowly. This gives the dissolved nitrogen in the diver's body time to escape without bubbling.

The inflation mechanism works manually by pulling the ring handle at the base of the unit. This, in a series of stages, pushes the piercer to puncture the CO₂ bottle, releasing the gas to inflate the life-jacket.

Mark Franklin

Every attempt is made before abandoning ship to radio the position of the vessel to the coast guard. But help, in the form of another ship or a helicopter, may be several hours or even days in coming. It is vital, then, that survivors can signal their whereabouts from several kilometres away.

Signalling

During the day, orange smoke canisters, sea dye markers, and sun-reflecting mirrors are especially useful in attracting attention. At night, rockets, red hand-held flares or red

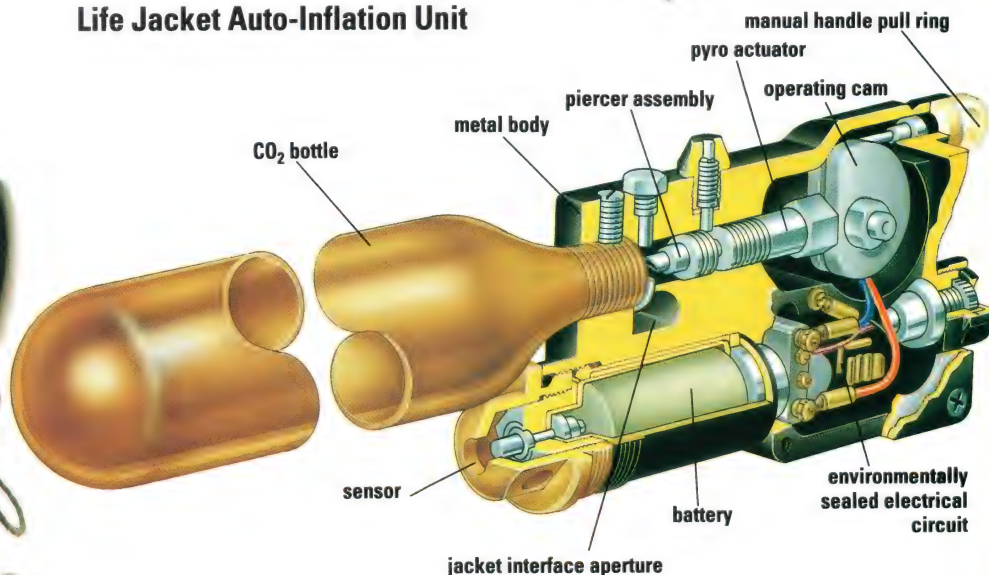
parachute flares may be used instead.

Today, the most effective signalling systems are emergency locator transmitters (ELTs) and emergency position indicating radio beacons (EPIRBs). These small, lightweight beacons are shock-resistant and begin transmitting automatically when they come into contact with water. The signal, which is broadcast continuously on emergency distress frequencies for at least 48 hours, may be picked up by passing aircraft, ships or a rescue satellite system. If received by satellite, the message is relayed to an international network of ground stations and then to a rescue control centre.

Surviving for long periods under

A water-activated battery that energizes an electrical circuit ensures that an unconscious pilot or crew member will be supported by the life-jacket.

Life Jacket Auto-Inflation Unit



water poses even more severe problems. Deep-sea divers not only carry their own air supply with them, they also need protection from the build-up of pressure with increasing depth.

An aqualung or SCUBA (Self Contained Underwater Breathing Apparatus) ensures that a diver can breathe normally at all times. Between one and three 7-litre air tanks are

to counterbalance the increasing water pressure. So, at a depth of 10 metres, one tank would only last about 28 minutes, while at 20 metres down, the supply would run out in just over 18 minutes.

The pressure in the air tanks is often over 150 times normal atmospheric pressure. But the pressure of air the diver actually breathes has to be the same as the surrounding water pressure. The air must always come

Martin-Baker



SENDING AN SOS

Hand stars, carried aboard lifeboats and other small craft, fire two red stars with an interval of three to five seconds between them. The stars reach a height of about 45 metres and burn for roughly five seconds. For signalling over greater distances, parachute flares are used. These are rockets, fired from a plastic launching tube, that open and release a red flare beneath a four-string parachute. The light burns for over 40 seconds, as it drifts down at a rate of 4.6 metres per second, and can be seen from 45 kilometres away on a clear night. During the day, fireworks are difficult to see, therefore orange-coloured smoke flares may be used instead.

in at the precise rate the diver needs. Both these requirements are handled by the demand regulator.

By breathing in, the diver automatically operates a spring that opens the inlet valve. This lets air flow in from the tank. When he breathes out, the supply through the inlet valve is closed off, and the used air escapes through the outlet valve.

Air underwater

The greatest danger is if the air supply starts to run out. To signal this, some aqualungs have a kind of early warning. When there is only enough air to let the diver return to the surface safely, the air flow is restricted, making breathing more difficult. By pulling a by-pass lever the diver can restore the normal supply, but he knows he must come back up immediately.

SCUBA gear can be used down to

depths of about 60 metres. For thermal insulation, the diver wears a wet suit made of 5-millimetre neoprene rubber. This traps a thin layer of water next to the diver's body. Since this layer, warmed by the diver's body heat, cannot escape, it acts as a blanket against the cold of the sea.

Hard suit

For survival at greater depths, a hard suit is essential. This completely surrounds a diver like a massive, outer skeleton. One kind of hard suit, known as the Type IV JIM, is made from glass-reinforced plastic with a clear dome of plastic over the head. The



A data-gathering ship operated by the Meteorological Office, collects such information as wind speed and direction. Visible on the supertanker (above) is its satellite-receiving equipment – the white dome.

D Parker/Gotaas-Larsen/SPL

diver can be lowered safely to depths of up to 610 metres for periods of up to six hours. Further, because the air inside JIM remains at normal atmospheric pressure, there is no need to decompress on the way up.

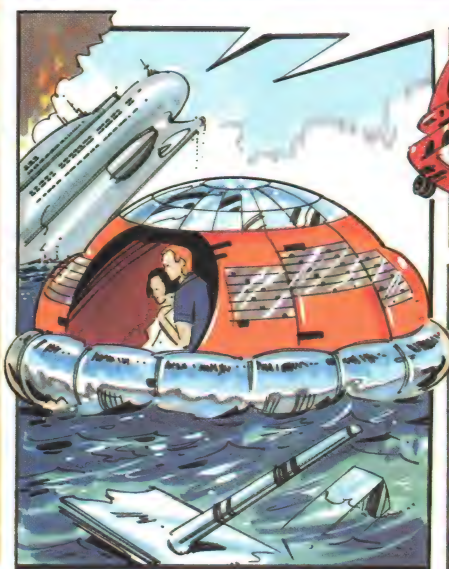
Even deeper dives have to be

made using specially-reinforced vessels called submersibles. A few of these are able to descend to the bottom of even the deepest ocean trenches, about 11 kilometres down, and they may be either manned or operated by remote control.

INTO THE FUTURE



▲ Waist pouches will contain inflatable lifeboats equipped with collapsible umbrella structures made of photovoltaic cells that harness energy from the sun.



▲ The solar energy will provide power for the lifeboat, warmth to prevent exposure, and the means to desalinate water, while the canopy will act as a heliograph.



▲ Each passenger will wear a signalling device attached to a wrist band, capable of transmitting signals in all atmospheric conditions and over infinite distances.

Joe Lawrence

Q THE STRIP

Q RAILS

Q FUNNY CARS

WHAT A DRAG

The fastest dragsters can accelerate from 0 to 60 km/h in less than one second. They cover the first 200 metres in just over three seconds and finish the standard quarter-mile - 402 metre - track or 'strip' a mere two seconds later.

By that time, the supercharged dragster may be travelling at over 500 km/h and require a parachute to bring it to a halt. There are four distinct classes of dragster. These are known

as professional, sportsman, two-wheelers and exhibition. But they all run over the same quarter-mile distance and down the same strip.



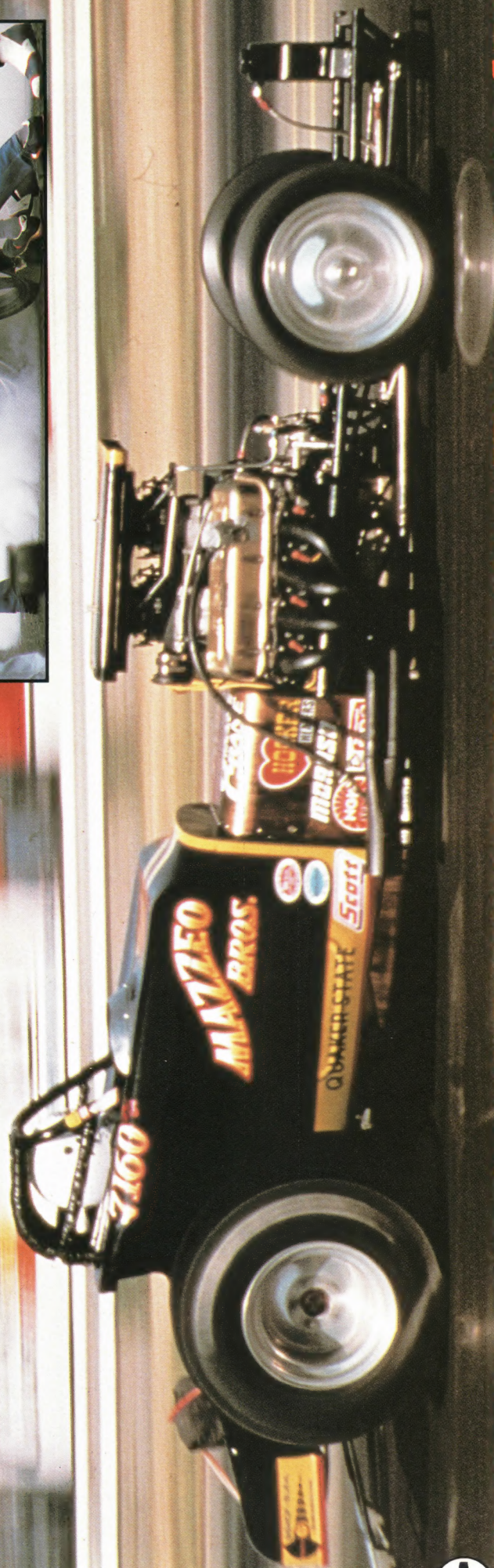
Nitromethane

The professional class consists of the top fuellers, which are drag racing's equivalent of Formula One Grand Prix racing cars. The engines may be no bigger than 500 cubic inches - 8,193.5 cc - in capacity, but they run on highly explosive nitromethane and

Drag racing is labour intensive. Between each quarter-mile race the oil and tyres must be changed and up to 16 spark plugs must be replaced by a team of mechanics to get maximum performance from the dragster.



JP Lentant/Vandystadt/Allsport





At the start of the run, the engines explode into life with flames and smoke everywhere. It is not unusual for the team mechanics to set the rear tyres ablaze just before starting to get maximum grip on the track. The standard practice, though, is to spin them in water until they are hot and sticky.

The most distinctive thing about these cars is their appearance. They usually have a 7.5-metre-long ultra-

light chassis, with small, aircraft-type wheels at the front and big and smooth motor-racing 'slicks', at the rear.

They have wedge-shaped carbon-fibre bodies, streamlined to reduce drag which makes them look like stretched-out racing cars. They are tested in wind tunnels for the minimum drag co-efficient, which means having least resistance to air flowing over the car.

Fibreglass

Some classes of drag racers, known as 'funny cars', have fibreglass replica bodies, which resemble standard production saloon or vintage cars, built

Funny cars have replica fibre-glass bodies that sit over the dragster itself, giving the impression that the vehicle is just a souped-up street car.



The wheels and their treadless 'slicks' are spun – often in baths of water, which give off plumes of white smoke – to warm the tyres. This makes them sticky and gives better traction.

Sutton Photographic

can produce enormous power.

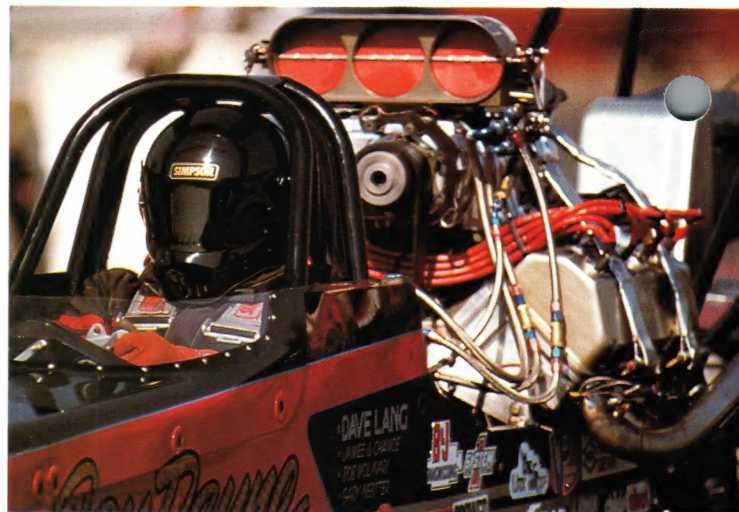
Besides the expense of the car, which can be over US\$200,000, running a dragster is not cheap. One litre of nitro costs around \$10 and a five-second run can consume between 55 and 70 litres. Each cylinder of the V-8 engines uses two spark plugs that have to be replaced after every run because the electrodes get burnt off – that's 16 plugs per race.

Similarly, 11 litres of oil are used for every run, and it gets so contaminated with fuel that it cannot be recycled for at least 18 months.

A supercharger compresses the fuel-air mixture and forces it at great speed into the cylinders of the dragster's V8 engine, producing extra power.

Mike Powell/Alisport

Riding the rail is extremely dangerous. Drag racers wear Nomex fire suits, face masks and are equipped with a remote oxygen supply. The cockpit is surrounded by a tubular steel cage.



Mike Powell/Alisport

on a three-metre-long special chassis.

These cars reflect the origins of the sport in the United States after the Second World War. Teenagers started racing each other in 'souped-up' cars, which had been stripped of all refinements to save weight.

They would race between traffic lights down the main 'drag' or street, until the authorities considered it to be too dangerous and set up proper tracks on the many airfields left over after the war.

'Read the tree'

Even today, the start is signalled by a system of lights called a 'Christmas Tree', which resembles an elaborate traffic light. One of the skills of the drivers is being able to 'read the tree' – that is, anticipate when the green

left-hand rotor driven by belt

fuel-air mixture drawn in through carburettors mounted on casing

left-hand rotor turns right-hand rotor by gears

belt tensioning pulley

driving pulley on crankshaft

inlet manifold

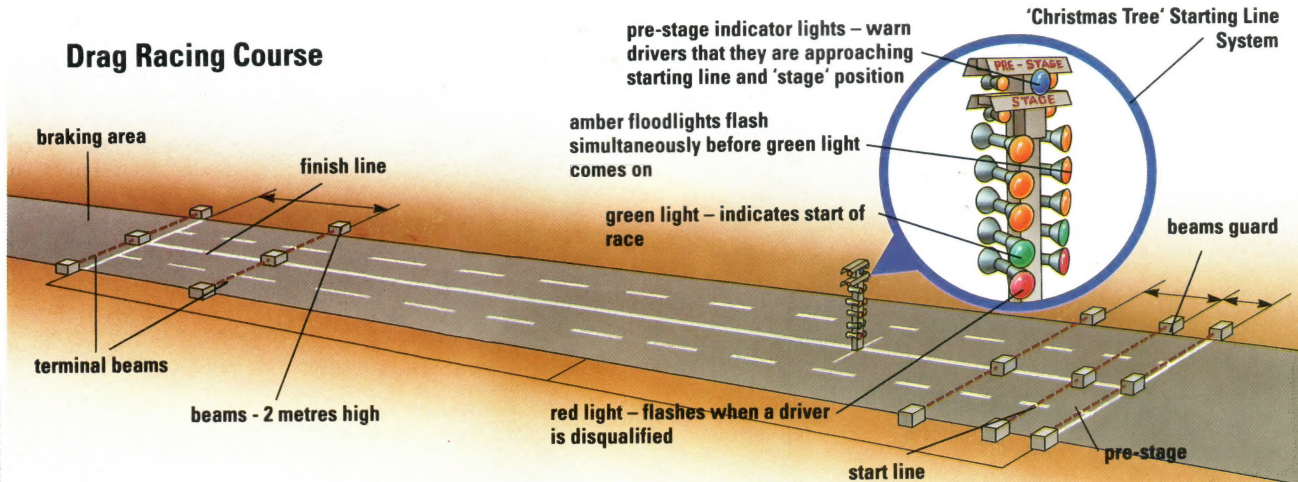
rotors mesh without touching

Roots Blower

Mark Franklin



Drag Racing Course



Mark Franklin

The dragsters slowly nudge into position. The top light on the 'Christmas Tree' will flash if they are too far forward, the third will flash if they are too far back.

start light is coming on so that they can 'steal the march' on the other car.

There is still the 'Street' class of racers, which are basically the type of cars you would see in the high street, except that the silencers are often

Dare-devil drag bike riders lean forward on their machines to make themselves more aerodynamic. Unlike on standard street motorcycles, there are no foot pedals. All the controls are operated by hand.



under their qualifying time.

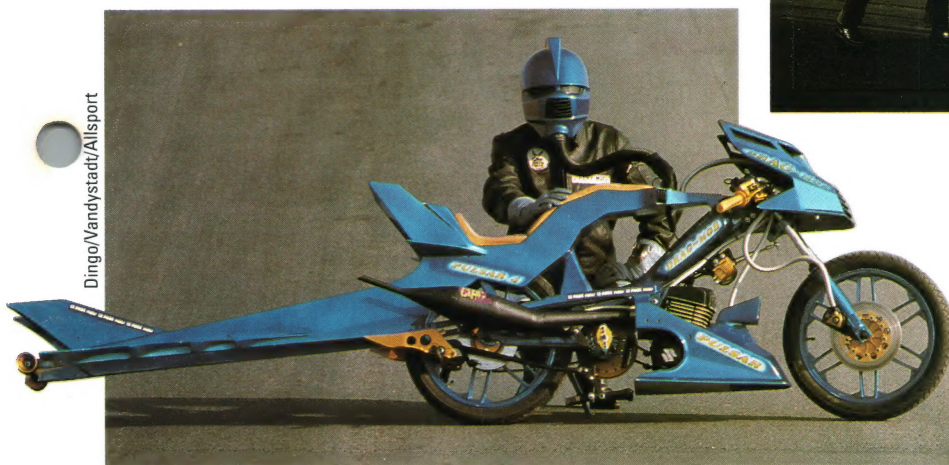
So cars that race head-to-head must try to beat their opponents while not finishing too quickly – 'braking out' as it is called. It is not uncommon to see drivers 'sandbagging' or locking their brakes as they cross the finish line to avoid going too fast.



'Doorslammers'

The highest and fastest class of 'doorslammers' – saloon cars with traditional body shells – is the Pro

P Behar/Vandystadt/Allsport



Dingo/Vandystadt/Allsport

'Wheelie bars' stop the bike flipping over on its back when the rider lets out the clutch and the huge force of the engine engages the back wheel.

removed to make the cars sound much louder. This is the beginners' level where newcomers start their career in drag racing.

The next stage is 'Super Street' racing, using modified British or American sports saloons with super-charged performance engines transplanted into them. Even if their owners no longer drive them on the roads, they must be 'street legal' and have a certificate of roadworthiness to be eligible to compete.



Disqualified

Like the Street classes, 'Super Gas' cars are performance-limited – that is, they disqualify themselves from competition if they complete the course

Mike Powell/Allsport

THE LANGUAGE OF THE STRIP

Blower: A supercharger.
Burnout: Spinning the rear slicks.
Bug catcher: The three- or four-port manifold that sits above the blower case.
Cherry: A red disqualification light.
Christmas tree: The start lights.
Flathead: An engine with a flat top.
Gasser: A car that runs on petrol rather than nitromethane.
Headers: The exhaust manifold system.
Hemi: An engine with a smooth hemi-

spherical top to the inside of the cylinder for optimum gas flow.

Laying rubber: Spinning the slicks as the dragster takes off from the start.

Mill: Engine.

Sandbagging: To brake heavily to prevent breaking the qualifying time.

Slasher: Automatic transmission.

Slicks: Treadless tyres.

Shutdown: To beat an opponent.

Wheelie: To accelerate so fast that the front wheels leave the ground.



Just amazing!

SPEED THRILLS

THE HIGHEST SPEED REACHED BY A DRAGSTER OVER THE QUARTER MILE COURSE WAS 631.732 KM/H AND THE FASTEST QUARTER MILE JUST 3.58 SECONDS.



Paul Raymond

300 km/h and cover the 400-metre course in around seven seconds.

Much cheaper than Pro Modified or Top Fuellers are the Pro Competition cars, or Top Alcohol Dragsters. They run on methanol, which is nearly ten times cheaper than 'fuel' or nitromethane, and the wear and tear on the engine is less.

But using the three-speed low-gear engines, they can reach speeds in excess of 370 km/h, covering the course in around six seconds.



Drag bikes

This level of performance is similar to the top fuel drag bikes, which run on 95 per cent nitromethane and 5 per

The tremendous acceleration raises the front wheels. Some dragsters cover the whole strip on their back wheels and have a Perspex floor so that the driver can see where he or she is going.

cent methanol. They have a standard four cylinder engine, supercharged and with a semi-automatic gearbox fitted. The front wheel is skinny, but the rear wheel may have a 38cm wide racing slick.



Strict rules

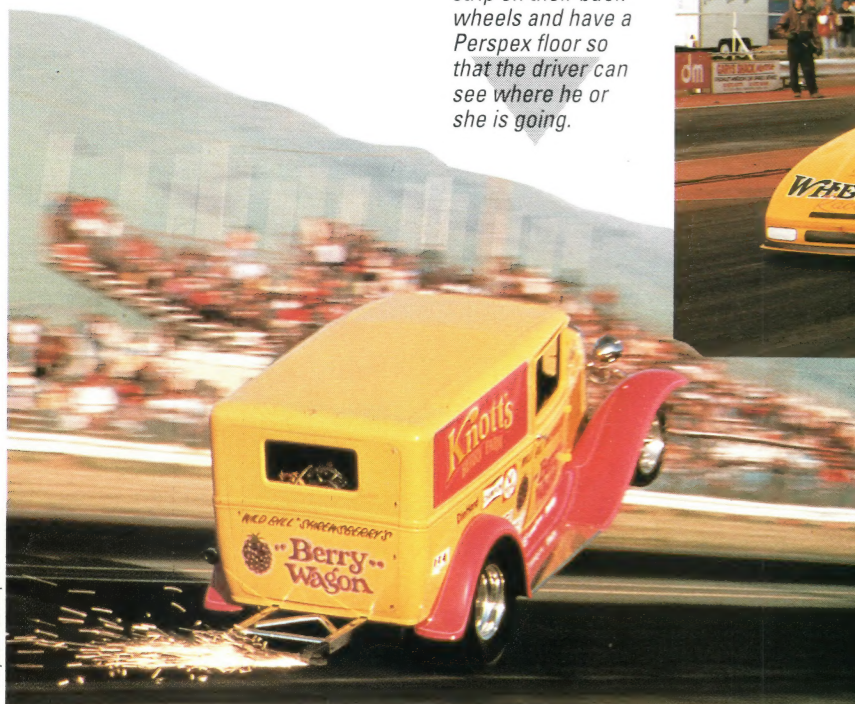
Other classes of bike are more like souped-up road machines, running on petrol only and with strict rules about rear tyre width, wheelbase length and

Production cars and cars that are completely 'street legal' are also raced down the quarter-mile drag strip in their own special classes.



David J Holloway/National Dragways Ltd

A replica vintage shell, of lightweight fibreglass hides a mighty V8 dragster engine that drives the car down the quarter-mile strip in under six seconds.



Vandystadt/Allsport

Modified class. These are usually modified production cars, backed by the companies that produce them, such as Ford and General Motors. The cars alone can cost \$250,000 each, but they can reach speeds of over

The high cost of drag racing means that sponsorship by automotive parts manufacturers is normally extensive.



even the height of the saddle. Another category is for street-legal machines, which can go up to 260 km/h.



Funny Bikes

Finally there are 'Funny Bikes', which have long, stretched-out frames that give them extra stability. They may look outrageous, but they can still reach speeds of 300 km/h on nitro-burning engines.

Mike Powell/Allsport

Vandystadt/Allsport

